MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

The Duties and Responsibilities of Membership

We of the membership of this Society deem such relationship no small privilege, no small opportunity, but we cannot separate honor and privilege from responsibility and obligation. It is a law of all human relation, a law indeed of life itself, inevitable and inexorable, that if we would enjoy and profit by privilege and opportunity, we must in return accept collateral duty and responsibility. So if you would enjoy and profit by what our Society has to offer, you must in turn be prepared to accept the duties and the responsibilities which are the inexorable compensation which must be rendered in return.

W. F. DURAND

(From charge to new members at A.S.M.E. Annual Dinner, December 8, 1926)

MARCH 1927

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DEPARTMENTAL

ADVERTISING

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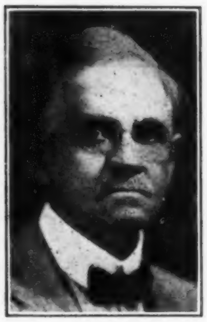

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T. D. Perry

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Wm. Braid White

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* * * * *

F. J. Chatel, technical engineer of the Delray Plant of the Detroit Edison Co., Detroit, Mich., completed his course in mechanical engineering at the University of Michigan in 1914. Since that time Mr. Chatel has been associated with the Detroit Edison Co., with the exception of a period of twenty-seven months during and after the War, when he served as engineering officer in the United States Navy. Upon his release from the Navy he became boiler-room engineer at the Connors Creek Plant of the Detroit Edison Co.

* * * * *

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* * * * *

W. A. Shoudy is associate professor of mechanical engineering at Columbia University and advisory engineer to the General Engineering & Management Corporation, New York City. He was graduated from Stevens Institute of Technology in 1899, and for a number of years was assistant professor of engineering practice at the Institute. He has been associated with the Brooklyn Edison Co., the J. G. White Engineering Corporation, the American Sugar Refining Co., and the Adirondack Power & Light Corporation. At the present time he is devoting his entire attention to problems relating to the generation of steam power.

* * * *

C. G. Stoll, vice-president of the Western Electric Co., was graduated from Pennsylvania State College in 1903 with the degree of B.S. He immediately entered the employ of the Western Electric Co. to begin his student-apprentice period. Two years later Mr. Stoll was put in charge of the Design Department of the Development Branch of the Engineering Department when it was organized. From that time Mr. Stoll advanced steadily through the various positions of engineer of methods, shop superintendent of the Antwerp plant, assistant general superintendent of manufacturing at the Hawthorne plant, Chicago, works manager, and general manager of manufacture. In July, 1926, he was elected vice-president in charge of manufacture to succeed the late H. F. Albright. He is a director of the company, a member of the Vail Medal and Personnel committees, and a director of the Manufacturers' Junction Railway Co.

Wm. Braid White, technical editor of *Music Trade Review*, and associate editor in charge of its western editorial department, Chicago, Ill., received his early education in St. Paul's School, London, Kings College, London, and Cambridge University. In 1898 he entered the piano factory of C. E. Byrne Piano Co., New York, and began a practical study of piano making. He was later with Kohler & Campbell of New York, studying tone regulation and action work. During the years 1915–17 he served as teacher in charge of a special school in player-piano construction, held under the auspices of the Chicago Piano and Organ Association.

* * * * *

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From 1914 to 1917 he was assistant professor of mechanical engineering at Columbia University. During all these years he acted as consulting engineer for numerous industrial concerns and individuals. Since 1917 he has practiced as consulting engineer. He is the author of numerous articles and papers on mechanical-engineering subjects.

COMING MEETINGS OF THE A.S.M.E.

Kansas City, Mo., April 4-6
White Sulphur Springs, W. Va., May 23-26

Keep in mind the dates and places for these two meetings. It will be well worth while. A glance over the program for the Mid-West Meeting at Kansas City next month indicates wide scope and sustained interest, while the White Sulphur Springs Meeting is our regular Spring convention. The technical sessions planned for the latter give promise of a program full of important and interesting papers. The location is ideal—one of the most beautiful spots in America—and is conveniently within reach of a large proportion of the membership, and the occasion will afford them an unusual opportunity to enjoy a short vacation. See the current issues of the A.S.M.E. NEWS for details of both meetings.

MECHANICAL ENGINEERING

Volume 49 March, 1927 No. 3

Production Control

How the Manufacturing Department of a Company Having 30,000 Employees and an Annual Output Exceeding $150,000,000 in Value and Comprising Some 13,000 Kinds of Apparatus, Functions in the Control of Production

By CLARENCE G. STOLL,[1] NEW YORK, N. Y.

THE subject of production control has received a great deal of publicity during the last few years, and from a theoretical standpoint there remains little to be added that is new or unique. The textbooks and journals of scientific management have presented its theory in minute detail, and for this reason the present paper will be confined to a description of the generally accepted principles of production control as they are applied in the Manufacturing Department of the Western Electric Company.

The manufacturing organization, which will be described, operates a plant which employs approximately 30,000 people, occupies over 3,000,000 square feet of floor space, and produces annually over $150,000,000 worth of manufactured product. All the well-known mechanical operations are employed in this manufacturing work, as well as those peculiar to the rolling of copper rod and drawing copper wire, and to the manufacture of ceramic products, paints, varnishes, and japans required for special purposes. The product manufactured involves the production of some 13,000 kinds of apparatus, requiring over 110,000 different parts.

Outline

For the purpose of clarity, the various phases of production control have been segregated under ten main headings, which are:

Organization	Inspecting
Plant Layout	Counting
Planning of Manufacture	Investment
Scheduling	Costs
Tracing	Results.

As to the ground covered, the first two are self-explanatory. Under the third heading, Planning of Manufacture, there will be discussed the estimating of cost of a proposed product, determining the manufacturing methods to be employed, and providing machinery and tools. The subject of Scheduling will cover the determination of the production program, placing the schedules and maintaining stocks. Under Tracing, the following of production through the factory will be considered. Inspecting and Counting will outline the methods set up for the determination of quality and for the counting and crediting of completed work. Under Investment and Costs the methods provided for their control will be discussed, and under Results the means whereby the management may visualize the entire process of production and measure the results obtained.

Organization

The organization in general is set up along functional lines, each major class of work being performed by a separate organization. This is illustrated by the organization chart shown in Fig. 1. It will be seen that there are seven major organizations, the duties of each of which are outlined in a general way on the chart.

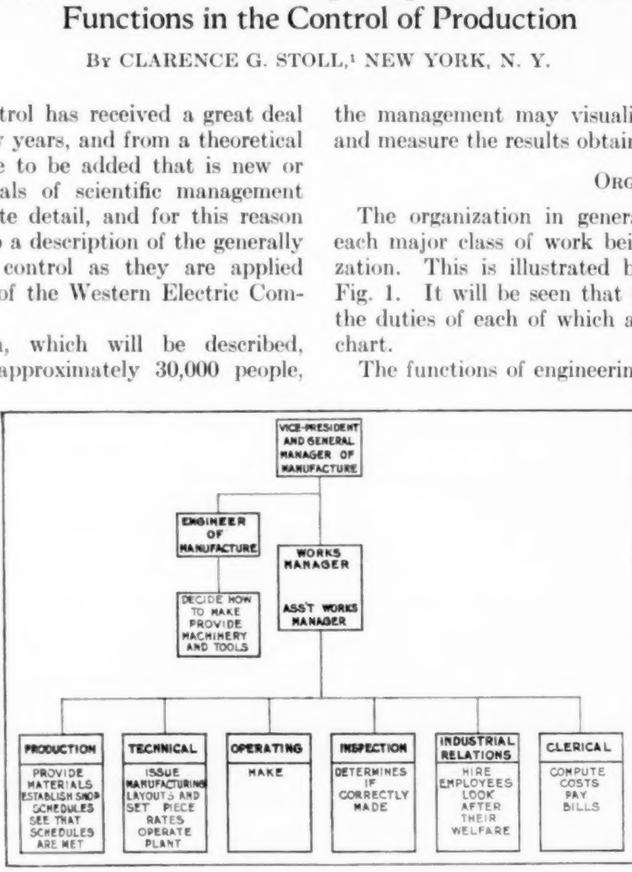


Fig. 1 Organization Chart

The functions of engineering for manufacture—or, as it is more commonly called, manufacturing planning—are as follows:

1 Estimate costs.

An expected hourly output for each operation, and the hourly labor values are established.

2 Analyze the design and prepare manufacturing drawings.

These drawings tell the factory in detail what is to be made and define the mechanical and electrical requirements.

3 Analyze for the manufacturing process.

The actual operations required to produce a part or piece of apparatus and their proper sequence are determined.

4 Provide the kind of tools, fixtures, gages, and other equipment to be used.

5 Provide the machines on which the manufacturing operations are to be performed.

6 Determine the kind and amount of raw material required and the form in which it shall be purchased.

In short, the Engineer of Manufacture organization devises and furnishes complete plans for all the operations of manufacture and provides the equipment required. It is the organization which carries the responsibility for keeping the works abreast of the developments in the art of manufacture.

The functions of the Production Branch are:

1 To receive and analyze the orders for product, and to determine the monthly requirements in terms of apparatus, component parts, and raw materials; and to order, receive, and stock the raw materials.

2 To determine the manufacturing intervals and issue work orders and schedules to the operating departments.

3 To follow the movement of the work in order to ascertain those jobs not progressing according to schedule.

4 To assist in removing any obstructions which may interfere with accomplishment.

[1] Vice-President and General Manager of Manufacture, Western Electric Company. Mem. A.S.M.E.

Contributed by the Management Division and presented at the Annual Meeting, New York, December 6 to 9, 1926, of The American Society of Mechanical Engineers.

5 To issue a weekly statement to all branches, listing jobs which are not progressing satisfactorily.
6 To count the product and give official credit for work performed.
7 To do all warehousing, trucking, and transfer work.

The plan of manufacture and the equipment supplied by the Engineer of Manufacture is received by the Technical Branch of the works organization and by them applied to the factory. The Technical Branch also provides the factory with instructions for manufacture in the form of layouts which definitely specify each operation to be performed, the tools and machines to be used, the speed at which each machine shall be operated, the containers in which the parts are to be handled, the amount and kind of raw material to be used, and the departments to which the parts shall be routed for inspection, counting, and subsequent operations.

MANUFACTURING LAYOUT RECORD

DEPT.	OPERATIONS	TOOLS AND SPECIFICATIONS	MACHINES
338	Perf. (4) .093" holes and Blank	P&D C-16374	#3 Bliss
	Tumble	Sawdust and pumice	Tumb. bbl.
	Flatten	P&D C-57827	#19 Bliss
641-2	Inspect		
263	Count		
333	Bore 53/64" hole	Jig C-2295 Use gauge pin assembly Det.#16 Gauge plate Det.#2 in pos. H. Det.#7 in position "A" and gauge pin, Det. #9 in position 1 and 8. Combination c'bore and c'sink tool C-48318, ground to suit	1 Sp. B.D.P.
	Grind off c'boring burr in	Disc C-72199	Disc. Motor
	Countersink (4) holes	Sp. Gr. Drill	1 Sp. B.D.P.
	Remove Grinding burr in 53/64" hole	Scraper	Bench
642-3	Inspect		
251	Count		
343	Acid Dip	Spec. 50029, Method #9-B	
	Dry	Spec. 50032, Method #1-A	
643-1	Inspect		
255	Count		
230	Store		

DELIVER IN CONTAINER NO. 782 UNLESS OTHERWISE SPECIFIED

ISSUE 2-19-26	SHEET NO.	NAME OF PART Face Plate, DRWG. P-88235
REPL. ISSUE 12-28-25	SHEETS IN SET	APPARATUS Misc. Signals

FROM STORE	QUANTITY PER 1000 PARTS	RAW MATERIAL NUMBERS	PART NO. OR DESCRIPTION OF STOCK	DELIVER TO DEPT.
229	35.#		1064" x 1-9/32" x 72" Grade "A" Half Hard Brass Sheet, Spec. 57504 53 pcs. per sheet 1-9/32" x 72" (On 1-11/32" centers) 18.87 - sheets 1-9/32" x 72" per M Pcs.	338

ISSUED BY PLANNING DIVISION 6430 — DO NOT REMOVE THIS LAYOUT FROM BINDER

FIG. 2 TYPICAL LAYOUT FOR THE MANUFACTURE OF A SMALL PART

The Technical Branch establishes the piece-work rates to be used, follows the manufacturing work through its early stages to determine whether the methods and equipment employed give the results expected, and accepts the burden of overcoming difficulties that may be encountered in the operation of the plan.

This organization also acts as the works landlord, operating the power plant and service systems, maintaining the grounds and buildings, and supervising the watch and fire-protection service.

The Industrial Relations Branch handles the various personnel activities of the works, employment, physical-examination facilities, hospital, restaurants, contacts with employee clubs and associations, and application of pension and benefit plans.

The Operating Branch comprises all of the departments which are actually engaged in the operation of machines and the handling of productive labor in manufacturing the product. From the outline of the functions and duties of the preceding branches, it will be seen that every facility is furnished to the Operating Department, i.e., manufacturing drawings, layouts instructing them how to proceed, machines, tools, orders, materials, and labor. It is the operating job to coördinate and utilize efficiently the equipment, materials, and labor provided in accomplishing, on scheduled time, the desired results, as indicated on the drawings.

The Inspection Branch is responsible for maintaining the quality of the product from the receipt of raw material through each process operation to the final inspection of the completed apparatus. The inspection operations are conducted by groups throughout the plant located adjacent to the Operating Department whose work they are inspecting.

The Clerical Branch is the comptroller of the works. It sets up the clerical system under which the works shall operate, prescribes routines, computes the payroll, and pays the help and the bills for materials and supplies. This organization also compiles the cost and reports showing results.

Each of the organizations just described is complete in itself, having its own superintendent and staff working, of course, in coöperation with the other branches.

PLANT LAYOUT

In the arrangement of plant equipment there are two common methods open to the manufacturer. The first, and probably the most extensively followed, is the segregation of machinery and equipment according to class of work. Under this scheme one group or department performs drilling work only; another, punch-press operations; another, milling, and so on. During the process of manufacture each part passes in proper sequence through these various groups, until it reaches a department engaged entirely in assembling.

The second method is that of assigning to each group the equipment required for the complete manufacture of an assembled unit.

Which of these two arrangements is the more economical depends upon the type and variety of the products to be made and the size of the schedules. For quantity production the former method offers various advantages. Chief among these are a high degree of flexibility in manufacturing capacity, maximum machine activity, and minimum duplication of equipment. Furthermore, in grouping machines by types a high degree of efficiency may be attained as a result of specializing the efforts of the operators, and by having all of one class of activity under the supervision of a group of skilled artisans. This arrangement tends to promote a higher development of each line of manufacture and minimizes the problem of training unskilled labor.

The disadvantages are increased handling, necessity for process inspection between departments, and the setting up of a system for controlling production and coördinating the efforts of each group.

The second scheme of plant arrangement, which groups the equipment required for the complete manufacture of a product or a line of products within one department, is chiefly applicable to jobs which require the use of special equipment or to jobs of small quantity. Its advantages are the ease of schedule control and the elimination of interdepartmental difficulties by having the entire manufacturing process on each product under centralized supervision.

The chief disadvantages of this arrangement are high investment in plant and the fact that labor and supervision do not usually rise to the high level of efficiency attained by the specialized group, both of which will be reflected in cost and quality.

In general, our work lends itself well to the specialized method, and that is the type of organization through which the great majority of our products pass. There are, of course, some departures therefrom in the case of products which require a large amount of special equipment or are manufactured in small quantity, and in the case of products which during the various stages of construction are very susceptible to damage in handling.

In carrying out this general scheme of plant layout, the specialized departments in our buildings of the multi-storied type are arranged so that the work progresses vertically. The raw-material storerooms and heavy-machine departments are on the ground floor, the lighter-machine departments on the second and third floors, the finishing departments on the fourth floor, and the assembly work and part storerooms on the top floors. In the single-story buildings designed for special products, the progress of the work is, of course, in a lateral direction.

Planning

The Cost Estimate. An accurate forecast of the manufacturing cost of a new article before its manufacture is undertaken is no doubt recognized as one of the fundamentals of modern industry, and for this reason the accuracy of the cost estimate is of prime importance. The cost estimate should reveal whether the contemplated design is practical from a manufacturing standpoint, how the capacity of the existing plant will be affected, and how large an investment in new plant and equipment will be required. All of these are contributing factors in determining the commercial practicability of the new design.

At one time cost estimating was largely a matter of guess, comparison, and simple arithmetic. However, as we gain in experience and knowledge from year to year, the task of predicting costs is becoming less one of estimating and more one of reference to standard data compiled from previous observation and experience. As we continue to learn more of the capabilities of men and machines and make records of them, it is possible to establish time standards in the form of curves and formulas from which time values may be calculated with a high degree of accuracy. Estimating is consequently becoming more and more a matter of intelligent use of data already compiled in the form of standards.

Design Analysis and Preparation of Drawings. The design of the new product has a very important bearing on production, and for this reason a thorough analysis of the design of each new article is made in advance of its actual manufacture. It is frequently possible by this means to eliminate features which would prove troublesome in the factory. Changes which will contribute to more economical manufacture or permit more rugged tool construction may be made, thus eliminating interruption to production by tool failure. Study of the design may disclose that it can be simplified, that it contains structural weaknesses, or that modification will permit of greater tolerances. It may be practical to substitute a softer metal; increase the radii of bends on formed parts, so as to eliminate possible tool trouble; or change the size or shape of a hole to simplify tool construction and reduce maintenance. Such considerations have a very important bearing on the facility with which an article may be produced, and on its cost.

After the final design has been approved, the manufacturing drawings are prepared. These consist of detail drawings of each part, assembly drawings showing how the various parts are associated, a stock list showing the kinds and quantities of parts required, and a test sheet which shows the mechanical or electrical requirements which the apparatus must fulfil in order to assure satisfactory performance.

The Manufacturing Analysis. This analysis involves the determination of the logical and most economical sequence for the performance of the operations, and the selection of the best available methods for manufacture, with special attention being given to the quantity of parts required and the accuracy with which they must be made. These factors have a very important bearing on the investment in tools and equipment, which in turn is reflected in cost.

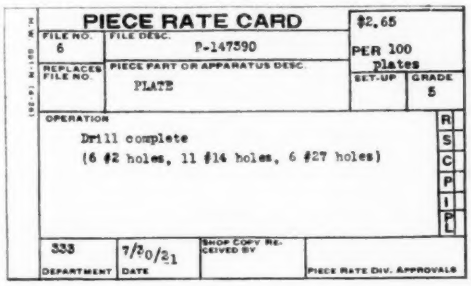
When the quantities to be manufactured are large, a relatively heavy investment in equipment is justified to permit building multiple tools and combining operations, or even the construction of special machinery, in order to obtain higher outputs per unit of labor, which, of course, should more than offset the heavy investment during a period well within the life of the equipment. On the other hand, when the quantities are small the cost of the more efficient types of tools is not usually warranted, and those of simple and inexpensive design must be used at a resulting higher labor cost. In each case the procedure which will result in the lowest total cost must be determined.

Accuracy is also an important consideration, as the productivity per man- or machine-hour is, in general, inversely proportioned to restricted dimensional limits and tolerances. Excessive costs from this source are a reflection of the greater care that has had to be exercised, of the necessity for a high grade of labor and tools, and of high maintenance to tools and machines to keep them in condition to produce parts within the required accuracy.

The manufacturing analysis prescribes the sequence of operations, the tools and machines to be used, machine feeds and speeds, and the kind and quantities of material to be drawn from storerooms. This information, when received by the Technical Branch, is issued in the form of a manufacturing layout which serves the Operating Department as a complete instruction for the manufacture of the part. A typical layout for the manufacture of a small metal faceplate is shown in Fig. 2.

Upon the technical organization also rests the responsibility for designating the grade of labor to be used in performing the various operations. This is shown on the piece-rate card, Fig. 3, which also specifies the rate to be paid the operator for work done.

Providing Equipment. At the time of preparing the manufacturing analysis, construction or purchase orders are originated for all the tools, machinery, and equipment required to follow out the manufacturing methods which have been prescribed.



PIECE RATE CARD

FILE NO. 6 | FILE DESC. P-147590 | $2.65 PER 100 plates

REPLACES FILE NO. | PIECE PART OR APPARATUS DESC. PLATE | SET-UP | GRADE 5

OPERATION

Drill complete
(6 #2 holes, 11 #14 holes, 6 #27 holes)

R S C P I PL

333 DEPARTMENT | 7/20/21 DATE | SHOP COPY RECEIVED BY | PIECE RATE DIV. APPROVALS

Fig. 3 Piece-Rate Card

These orders are forwarded to the Tool and Machine Design Department for design or editing, and then to the tool shop for construction, or to the buyer for purchase.

Scheduling

The Forward Picture. In order to plan and execute a well-balanced production program, some indication of the volume and character of future business is necessary. The first of the activities of the Scheduling Organization consists, therefore, of setting up a forward picture of the probable manufacturing activity. This forecast, compiled semiannually, is based on the orders on hand, past requirements, and future indications, and is expressed in terms of the major lines of the product. These product requirements are later broken down into individual parts in order to present a picture of the probable future activities of the various manufacturing departments such as the Machine and Assembly Departments. The semiannual estimate also provides a basis for a general survey of raw-material needs and is used in compiling advance raw-material requirements for use in contract or quantity buying.

While the semiannual estimate does not authorize manufacture and is subject to some revision as time advances, it assists materially in the maintenance of an even shop load, and permits increases and decreases in the production program to be made most economically. It also enables each organization to get its house in order somewhat in advance of a change in actual production rate.

The Schedule. For a factory handling a volume and variety of apparatus such as ours, the task of scheduling the work so that the deliveries of the numerous individual orders will be accurately coördinated requires a close analysis of two fundamental considerations: the process time allowance and the distribution of load. For accurately estimating process time allowances, records are maintained showing the average time required for each part and piece of apparatus to travel through the factory. The more closely the allowance for each part checks with the actual performance, the better is the Scheduling Organization enabled to plan an even distribution of the load. The economical operation of the factory depends very largely upon the accurate planning

of this distribution, since it is only by the elimination of peaks and valleys in the production chart that labor turnover can be minimized, and the alternate idleness and overcrowding of machines and floor space avoided. Such conditions invariably increase manufacturing costs.

Our products present perhaps every known type of scheduling problem. The demand varies from the year-to-year requirement of several million of one part to the special order for one of another part which may never be made again. Between these two extremes may occur the large order which will not be repeated and the small order which will be fairly constant from year to year. The control of this problem requires a careful analysis of each order, the maintenance of adequate process allowance records, and a definite "fitting" of each new order into the general production program.

Definite authorizations for the manufacture of each major type of apparatus are issued monthly. As they are derived from a number of sources, the summarization of all the monthly requirements on any one item would ordinarily present a complicated and expensive task. However, a mechanical tabulating system has been developed for which a card, Fig. 4, is originated each time the same item is encountered in our orders, and by mechanically sorting and combining these cards the total requirements

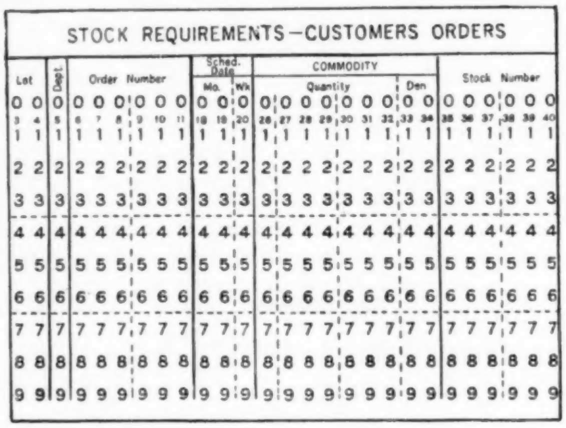


FIG. 4 CARD FOR USE WITH MECHANICAL TABULATING SYSTEM

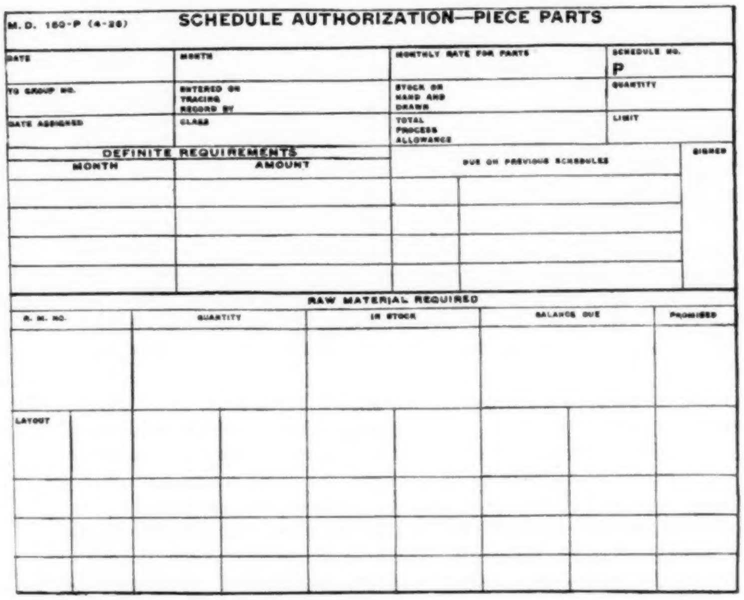


FIG. 5 SUMMARIZED SCHEDULE FOR FACTORY USE

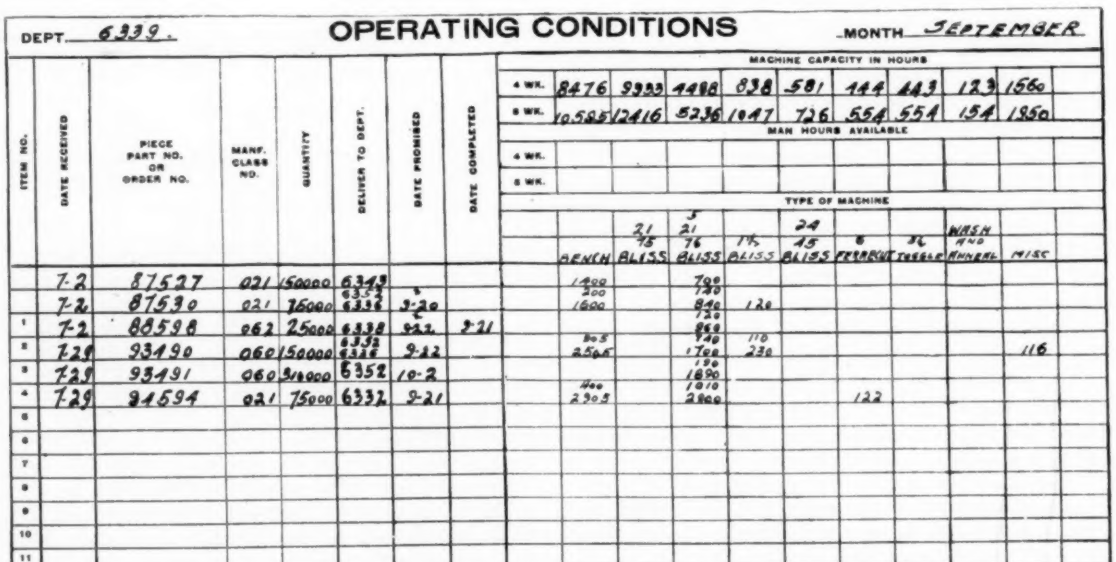


FIG. 6 OPERATING-CONDITIONS REPORT

can be readily compiled. In this way about 95 per cent of our preliminary summarizations which are necessary before proceeding with subsequent manufacturing steps are handled with a speed and accuracy which of course would not be possible by hand.

As each item of apparatus is assembled from a number of component parts which may be common to other types of apparatus, the summarization of the component-part requirements is also a somewhat involved problem. Here again the mechanical tabulating system may be used to even better advantage than in the preliminary summary.

For all standard-apparatus items, several sets of tabulating cards showing the requirements of component parts are maintained, each set for a different quantity of the item, so that by combining these sets the total requirements of the component parts can be readily compiled for a schedule of any size.

From the part requirements thus tabulated, summarized schedules are prepared for the factory. One of these is illustrated in Fig. 5. The schedules are then analyzed for the raw-material requirements. This information, obtained from the manufacturing layout, is posted to a master raw-material record, which collects for one kind of material, the requirements derived from the schedules of a number of different parts.

The general production program, which now represents the analysis of the sum total of all orders on hand, is distributed into monthly loads, and a card originated for each major piece of apparatus showing the required rate of production. In general, it is possible at this time to fit each new job into the general program and to determine when final delivery can be made, since standard intervals for each manufacturing operation have been previously set up from the process allowance records.

In the factory the schedules are supplemented by what is known as an "Operating Conditions" report, which is maintained by each operating department. One of these is shown in Fig. 6. The quantity of each part required for the month is converted into machine- and man-hours from preëstablished data, and the figures entered in their proper columns according to the type of equipment used. It will be seen that in a few of the columns more than one machine is listed, which signifies that the work may be performed on any one of these machines without affecting the cost. The cumulative total in any one column, when balanced with the total machine capacity for the type of machine involved and entered at the top of the sheet, readily shows any condition of overload or underload. By means of this sheet the foreman can readily determine the exact status of all jobs in the department, and is forewarned of the necessity for emergency measures. He is thereby enabled to control efficiently his activity and concentrate his equipment and personnel where required.

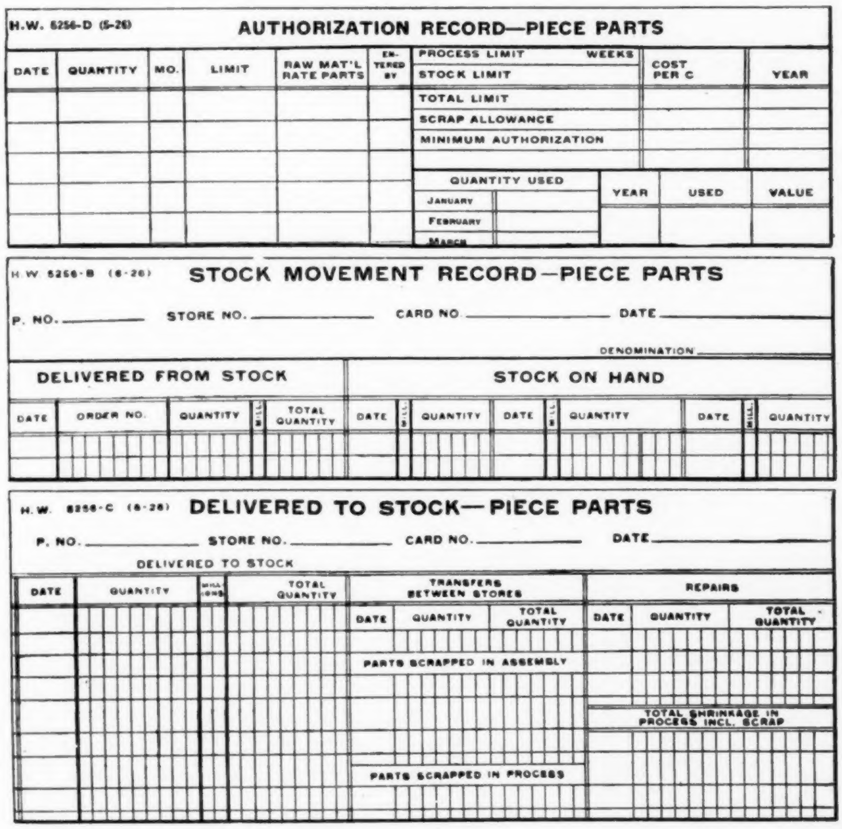
Maintaining Stocks. After the receipt of the definite apparatus authorization, considerable time must elapse for procuring raw material, the manufacture of the parts, and the assembly of the parts into the apparatus. To minimize this interval on standard product, sufficient stocks of all parts and raw material are maintained to meet the current monthly requirements and to supply any moderate additional needs which may develop.

The stocking of materials, parts, and finished products is conducted by a number of storerooms, each carrying a distinct class of articles, and located in close proximity to the source of demand for those articles. For instance, one of the raw-material storerooms carries all steel used in the form of bars, rods, and sheets, and since such materials are heavy, this storeroom is located as near as possible to both the receiving platform and the departments using this material.

In general, current requirements can be filled immediately from current stocks, and the monthly orders are to replenish this stock against anticipated requirements for the succeeding month. In maintaining stocks of apparatus and parts, it is of course necessary again to consider the required process intervals. The control of raw-material stocks is affected by the value and nature of the material, the conditions under which it may be procured from normal sources of supply, and the general purchasing policy in regard to the particular item.

Although the ordering and stock maintenance of apparatus, parts, and raw materials involves the control of over 100,000 separate items, these functions are controlled with a relatively small personnel by reducing the necessary clerical operations to a simplified form and establishing routines, formulas, and methods which will, as much as possible, function automatically.

Complete records on all items of stock are kept in a master file where they are readily accessible to the organizations interested. In addition to a complete description of the item and its accounting designation number and classification, master cards show past



H.W. 5256-D (5-26) AUTHORIZATION RECORD—PIECE PARTS

DATE | QUANTITY | MO. | LIMIT | RAW MAT'L RATE PARTS | ENTERED BY | PROCESS LIMIT WEEKS | STOCK LIMIT | COST PER C | YEAR

TOTAL LIMIT

SCRAP ALLOWANCE

MINIMUM AUTHORIZATION

QUANTITY USED: JANUARY, FEBRUARY, MARCH | YEAR | USED | VALUE

H.W. 5256-B (6-26) STOCK MOVEMENT RECORD—PIECE PARTS

P. NO. ______ STORE NO. ______ CARD NO. ______ DATE ______

DENOMINATION ______

DELIVERED FROM STOCK: DATE | ORDER NO. | QUANTITY | BILL | TOTAL QUANTITY

STOCK ON HAND: DATE | BILL | QUANTITY | DATE | BILL | QUANTITY | DATE | BILL | QUANTITY

H.W. 5256-C (6-26) DELIVERED TO STOCK—PIECE PARTS

P. NO. ______ STORE NO. ______ CARD NO. ______ DATE ______

DELIVERED TO STOCK: DATE | QUANTITY | BILL | TOTAL QUANTITY

TRANSFERS BETWEEN STORES: DATE | QUANTITY | TOTAL QUANTITY

PARTS SCRAPPED IN ASSEMBLY

PARTS SCRAPPED IN PROCESS

REPAIRS: DATE | QUANTITY | TOTAL QUANTITY

TOTAL SHRINKAGE IN PROCESS INCL. SCRAP

FIG. 7 PIECE-PART CARDS

monthly and yearly consumption, definite monthly requirements (as received from tabulating-card breakdowns), and anticipated monthly rates (as derived from the semiannual estimate). Piece-part cards such as illustrated in Fig. 7 and apparatus cards also contain ordering instructions such as the process interval to be allowed, stock limits to be maintained, shrinkage to be compensated for, the value of the item, and the minimum quantity which can be economically produced in one lot.

Raw-material cards like that reproduced in Fig. 8 show necessary purchasing intervals and any other information affecting the procurement of the material. Posting of information to this card file is performed by a carefully trained group of employees who are responsible for keeping the information up to date and for issuing all reports, balance sheets, and other information regarding the status of stocks. Master cards carry limits for overstock, ordering, and understock, and where fluctuations in the stock balance carry the quantities on hand past any one of these points, the item is signaled by the posting clerk for the attention of the individual responsible. In this way the condition of "live" items can be followed very closely, while dormant items come up for survey periodically.

Wherever possible, the computing of quantities for stock-re-

plenishing orders is governed by a basic formula, this method allowing the delegation of the ordering to a less expensive clerical force than would otherwise be required. Such standardization enables us to control stock balances satisfactorily with a relatively small force of ordering clerks, one clerk, in some instances, controlling 500 to 1000 separate items. While establishing more or less automatic controls does not always meet the requirements of unexpected demands, it is, in the main, satisfactory for our purposes. Overbalanced stock conditions, while not always preventable, can usually be minimized by a careful study of the situation encountered and the application of proper routines.

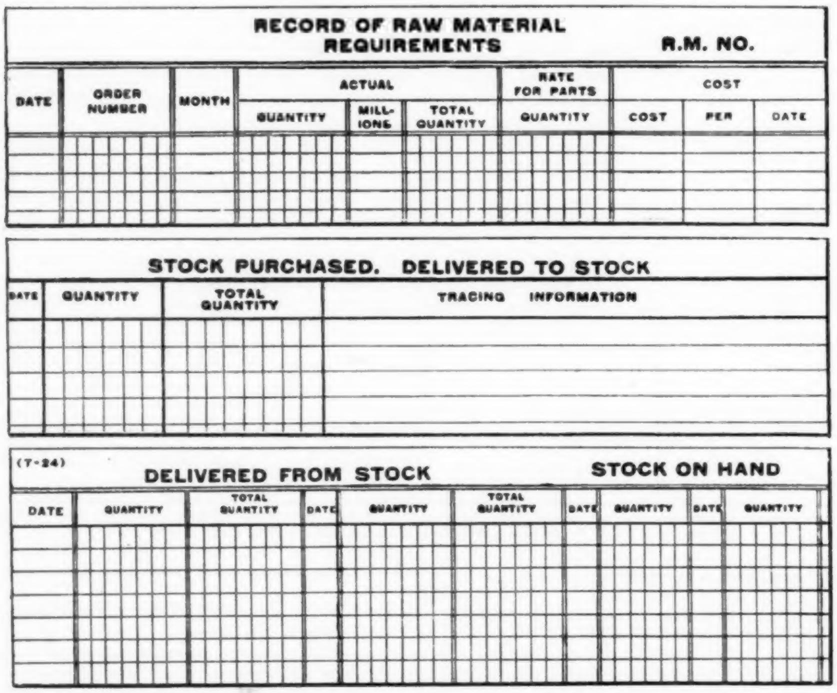

RECORD OF RAW MATERIAL REQUIREMENTS R.M. NO.
DATE | ORDER NUMBER | MONTH | ACTUAL: QUANTITY, MILLIONS, TOTAL QUANTITY | RATE FOR PARTS: QUANTITY | COST: COST, PER, DATE
STOCK PURCHASED. DELIVERED TO STOCK
DATE | QUANTITY | TOTAL QUANTITY | TRACING INFORMATION
(7-24) DELIVERED FROM STOCK STOCK ON HAND
DATE | QUANTITY | TOTAL QUANTITY | DATE | QUANTITY | TOTAL QUANTITY | DATE | QUANTITY | DATE | QUANTITY

Fig. 8 Raw-Material Cards

Tracing

In order to insure the delivery of parts and apparatus in accordance with schedule and to control investment, we maintain a tracing system. This system is operated by an organization whose function it is to coördinate the work carried on by the various branches. Upon this organization also rests the responsibility for seeing that all necessary steps are taken to insure the successful carrying out of the production program.

The need of a Tracing Organization is brought about chiefly by manufacturing difficulties and potential sources of delay which from their nature cannot be foreseen or guarded against without incurring a prohibitive investment in tools, machines, or material.

The orders placed in the factory are of two kinds: first, those which call for direct shipment, and second, those which are to replenish depleted stocks.

A copy of all orders and schedules placed in the factory and the required delivery dates on the parts and finished apparatus are furnished to the Tracing Organization. Knowing the quantity of each part required daily, it is the tracer's duty to watch the amounts of each available in stock, so that he may know on what part to exert pressure.

In order to keep the Tracing Organization acquainted at all times with the movement of the parts and apparatus scheduled, a centralized set of records is maintained. These records show the quantities on schedule, the date and amount of each individual delivery from the various operating departments on the layout, and the total deliveries to date. This record is compiled from copies of the delivery tickets which accompany all material in its progress from department to department throughout the process of manufacture. The tickets are immediately forwarded to the Tracing Organization for recording on the form illustrated in the lower part of Fig. 9. The schedule shown in the upper portion of that figure is, of course, a requisite part of the records, and is filed with the tracing records.

This record presents an exact picture of the progress of the work, and from it can be readily determined whether the parts and apparatus are moving in accordance with the needs, and whether the Assembly Departments are receiving a continuous flow of parts in order to insure uninterrupted production of the finished product.

Due to unexpected demands it is occasionally necessary to make deliveries earlier than originally scheduled, and in such cases the Tracing Organization assists the factory in rearranging its work with a minimum disturbance to other schedules. When such increases overtax the capacity of the Operating Department, it is the duty of the Tracing Department to analyze the problem and advise the foremen in what sequence the jobs should be produced.

The Tracing Department is so organized that each group handles certain major classes of apparatus. This includes the manufacture of the component parts as well as the assembly of the apparatus. It follows that the personnel of each group, from their constant association in the factory with the apparatus to which they are assigned, learn to know what manufacturing difficulties or obstructions may be encountered. Anything that seems likely to endanger the successful accomplishment of the program is

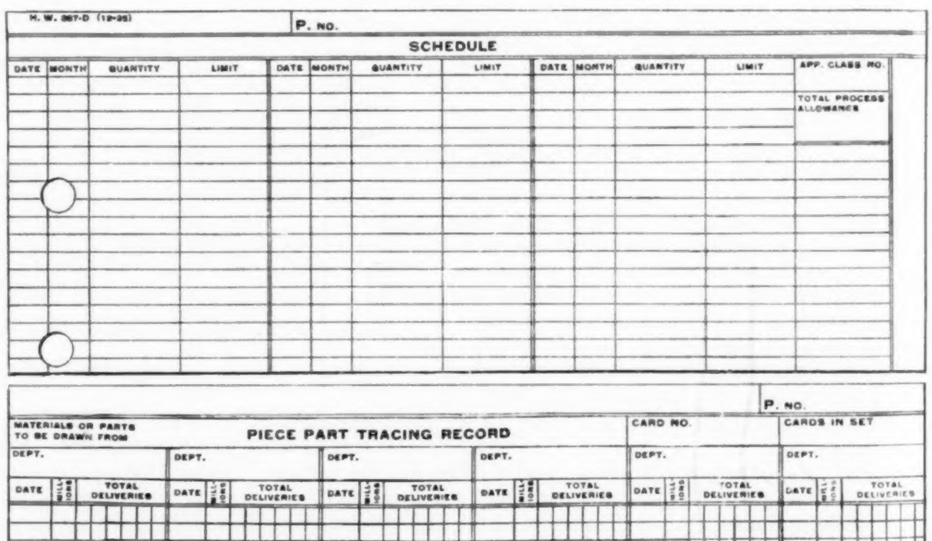

P. NO.
SCHEDULE
DATE | MONTH | QUANTITY | LIMIT | DATE | MONTH | QUANTITY | LIMIT | DATE | MONTH | QUANTITY | LIMIT | APP. CLASS NO.
TOTAL PROCESS ALLOWANCE
P. NO.
MATERIALS OR PARTS TO BE DRAWN FROM
PIECE PART TRACING RECORD
CARD NO.
CARDS IN SET
DEPT. | DEPT. | DEPT. | DEPT. | DEPT. | DEPT.
DATE | MILLIONS | TOTAL DELIVERIES (repeated for each department)

Fig. 9 Tracing Records

called to the attention of the organization functionally responsible. When occasion demands, it is also the function of the Tracing Organization to authorize emergency measures.

As an aid to the realization of the monthly rates of production on apparatus and parts, a report known as the "Trouble Bulletin" is issued weekly, in which those items not being produced at the required rates are emphasized. This report explains to the supervisors and executives interested the nature of the difficulties being encountered in maintaining production, such as tool breakdowns, raw-material shortages, etc. In this manner, the attention of the entire organization is directed to the apparatus or parts in trouble or headed for trouble, which usually permits corrective measures to be taken before production has been interrupted and delivery promises have been broken.

INSPECTING

The quality of the product is controlled largely by means of inspection. Inspection does not, of course, create quality, but its function is to measure it and to assist the Operating Organization in maintaining the desired quality levels. It does this by refusing to permit unsatisfactory material to proceed further in the process or to be shipped, and also by tabulating the results of inspection so that the responsible organizations may see where-in the product falls below the desired quality levels.

The labor required for inspection is generally of a somewhat higher class than that needed for ordinary production operations. There is, however, quite a wide variety in the kind of effort required, ranging all the way from simple mechanical gaging operations to making tests on complicated wire equipments which involve complex electrical circuits.

One of the most interesting phases of the evolution of inspection work is the development of equipment and methods whereby unskilled and semi-skilled persons are able to make intricate and difficult physical measurements and electrical tests with a relatively high degree of precision by ingenious adaptation of laboratory methods and facilities to ordinary shop conditions. Not only is high-class work of this kind carried on as a routine process, but the rate of production is far greater than would be expected by one acquainted only with the technical or scientific aspects of the job.

Such tests cover all kinds of physical qualities: the measurement of the thickness of mica sheets to the ten-thousandth of an inch, capacity of condensers to a few micro-microfarads, intervals of time to the thousandth of a second, and inductance and effective resistance to a tolerance of $^1/_{10}$ of one per cent.

Simplified, semi-automatic, and in some cases automatic testing and measuring methods are absolutely essential if apparatus having precise requirements is to be built in quantities at a low cost.

Control of quality begins with the inspection of raw material and embraces the careful watching of tools and machinery, a considerable amount of inspection on parts in process, and an extensive check-up on the finished product. In addition, an overall check inspection on a small percentage of the entire product is made by an entirely separate organization, to insure the maintenance of the general level of quality. Sampling methods are being utilized where they apply, and a general application of statistical methods and the theory of probability are not lost sight of in our efforts to obtain adequate quality control. Means are also provided so that the trends and the results of our inspection work can be visualized. This is accomplished by means of quality reports which are maintained for each major line of our product. Fig. 10 shows one of these.

COUNTING

As a large percentage of our manufacturing is performed on a piece-work basis, it is necessary to count materials and parts

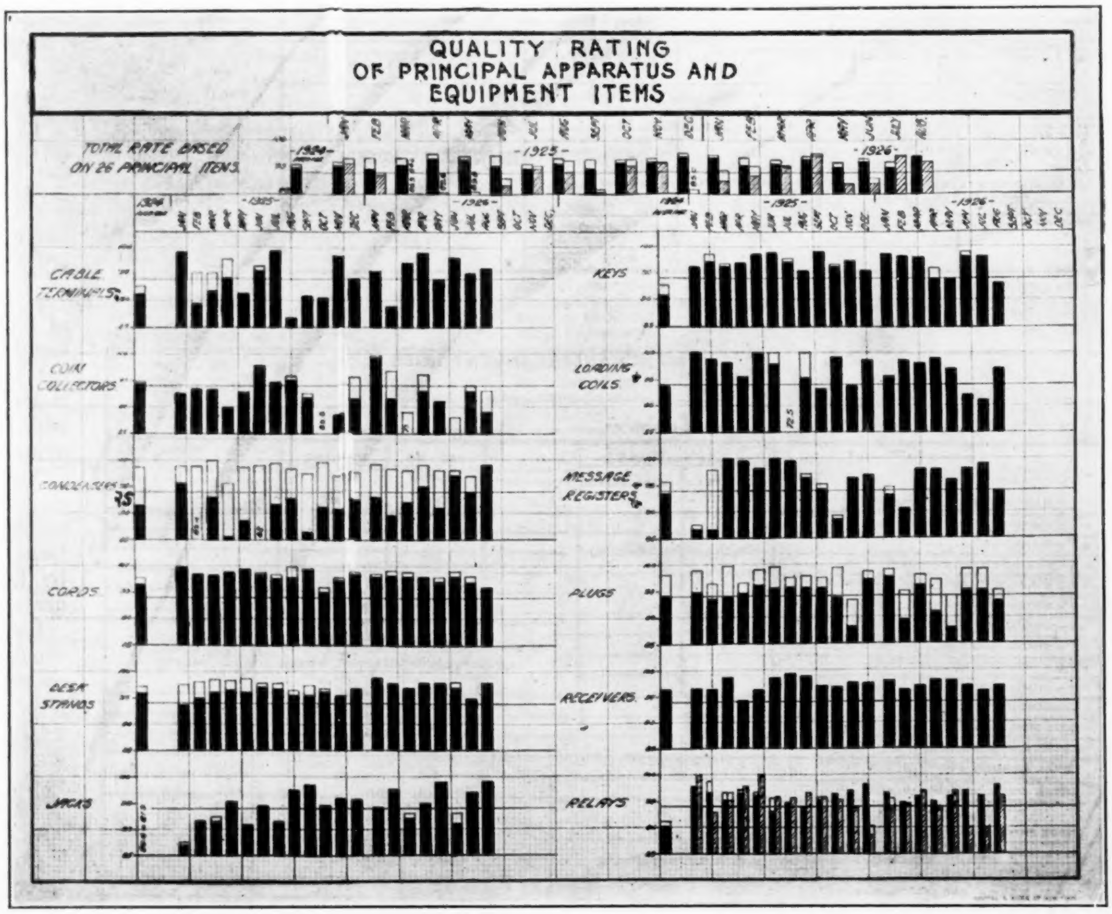


FIG. 10 QUALITY REPORT

after each operation performed in order to determine the wage due each operator. Counting operations are also required in receiving and delivering materials from stores and for the purpose of maintaining records. Counting rooms are located adjacent to inspection groups and to the manufacturing units served. From these counting groups, credit forms such as illustrated in Fig. 11 are distributed to the Payroll and Cost Organizations, to stock-record posting groups, and to tracing organizations interested in the progress of the particular material during manufacture. A count is also necessary in debiting and crediting against schedule when transferring materials and parts through successive organizations in the line of manufacture. This involves counting large quantities of parts, the greater percentage of which are small in size and difficult to handle as individual units. For this class of material we have applied very successfully the weight system of counting, through the use of "counting" or "ratio" scales. In operating this type of scale the material is placed on the scale proper and a small quantity transferred to a counterpoise pan

until the scale is brought into balance. The small quantity in the counterpoise pan is then counted by hand, and by comparing this count with the ratio of the scale, the total count of the quantity on the scale may be computed. Of course, in operating the scale the tare weight of the container must be canceled. Similar scales are used in counting deliveries from bulk stock in storerooms and for packing small parts in standard packages. These scales furnish results sufficiently accurate for credit purposes and the necessary records and statistics, and enable us to perform our counting operations at a relatively low cost.

H. W. 5046-N (5-26) TRACING RECORD 3-5			H. W. 5048-N (5-26) WEEKLY OR MONTHLY G. P. W. CREDIT AND DELIVERY TICKET 4 PAY ROLL RECORD				
TO DEPT.	GANG NO.	TICKET NO.	FOR SCHEDULE ONLY) ORDER NO. K	G. P. W. PERIOD		TO DEPT.	
ORDER NO.			APPLY ON ORDER NO.	SCHED. DATE	GANG NO.	TICKET NO.	
P. NO. OR DESC.			P. NO. OR DESC.				
	WEIGHT		FILE DESC.	WEIGHT			
QUANTITY GOOD			QUANTITY GOOD	FILE NO.	LABOR	DOLLARS	CENTS
DEFECTIVES PAID FOR	SET UP PRICE	NO.	DEFECTIVES PAID FOR	SET UP PRICE	NO.	XXXXXXXX	
SCRAP PAID FOR	PRICE		SCRAP PAID FOR	PRICE PER________		INSPECTED BY	
TOTAL DEFECTIVES	TOTAL DELIVERED TO DATE		TOTAL CREDIT		NO. OF TICKETS	COUNTED BY	
XXXXXXXX			TOTAL DEFECTIVES	NO. OF CONTAINERS			
FROM DEPT.	DATE OF DELIVERY		FROM DEPT.	DATE OF DELIVERY		POSTED BY	

Fig. 11 Counting Credit Forms

MERCHANDISE INVENTORIES

FISCAL MONTH OF________________192___

RAW MATERIAL, GROSS	ON HAND BEGINNING OF FISCAL YEAR A	ON HAND BEGINNING OF FISCAL MONTH B	PURCHASED, MADE OR TRANSFERRED DURING MONTH C	USED OR SOLD DURING MONTH D	ON HAND END OF FISCAL MONTH E	TOTAL PURCHASED, MADE OR TRANSFERRED F	TOTAL USED OR SOLD G
-1 - ALCOHOL, DENATURED "D"							
-2 - ALUMINUM							
-3 - ANTIMONY							
-4 - BRASS ROD AND WIRE, BASE SIZES							
-5 - BRASS ROD AND WIRE, OTHER THAN BASE SIZES							
-6 - BRASS SHEET, BASE SIZES							
-7 - BRASS SHEET, OTHER THAN BASE SIZES							
-8 - BRASS TUBING, BASE SIZES							
-9 - BRASS TUBING, OTHER THAN BASE SIZES							

	ON HAND BEGINNING OF FISCAL YEAR H	ON HAND BEGINNING OF FISCAL MONTH I	ON HAND END OF FISCAL MONTH J
EXPENSE SUPPLIES, GROSS			
PLUS MISCELLANEOUS INVENTORIES			
MINUS DEPRECIATION			
TOTAL EXPENSE SUPPLIES, NET			
TOTAL WORK IN PROCESS, NET			
PIECE PARTS IN STOCK, GROSS			
PLUS MISCELLANEOUS INVENTORIES			
MINUS DEPRECIATION			
TOTAL PIECE PARTS IN STOCK, NET			
PIECE PARTS ON MANUFACTURING FLOORS, GROSS			
MINUS DEPRECIATION			
TOTAL PIECE PARTS ON MANUFACTURING FLOORS, NET			
NET TOTAL FROM ABOVE (MERCHANDISE IN PROCESS)			
COMPLETED MERCHANDISE, GROSS			
PLUS MISCELLANEOUS INVENTORIES			
MINUS DEPRECIATION			
TOTAL COMPLETED MERCHANDISE, NET			
GRAND TOTAL MERCHANDISE, PROCESS AND COMPLETED, NET			

Fig. 12 Monthly Investment Report

Investment

One of the chief uses of our stock-record system is in the control of investment. All record cards are classified to show each item under which it should be included for inventory purposes. For every item on which a stock card is maintained, a corresponding tabulating card is established. To these tabulating cards are posted monthly the quantity on hand and the deliveries to stock during the month, the latter figure being used not for the purpose of determining the investment but for comparing receipts with consumption. Pricing and extending the tabulating cards is simplified by the use of a method requiring only a limited number of prices to cover all items. To illustrate: In extending the value of 100 articles costing $5 each, the same result could be obtained by adding one cipher to the quantity and pricing at $0.50 each. By following this method, we are able to evaluate our inventory by using only 39 basic prices. Tabulating cards bearing the same basic price are assembled and the quantities added, one price extension being applied to the total. Monthly investment reports, Fig. 12, furnish a complete picture of our manufacturing performance, showing values of stock on hand at the beginning of the month, quantities purchased or made, quantities consumed, and stock on hand or in process at the end of the month. For comparative purposes the figures as of the first of the year and the total purchased and consumed up to and including the current month are also given. Additional reports showing investment by classes of apparatus divided between material and piece parts in stock and in process, are issued regularly.

Costs

The control of the elements of costs is a vital part of production control. This is exercised by means of reports or charts showing the trend of cost levels instead of detailed costs of production, which latter fundamentally are historical and fragmentary in statistical value.

There are three fundamental elements of costs: namely, labor, material, and expense, the latter being covered in figured costs by factory overhead, or in our nomenclature, "loading."

Labor is largely controlled by conducting our manufacturing operations on a piece-work basis. Over 80 per cent of the labor used for the manufacture and assembly of our product is piece work, the remaining 20 per cent being controlled by comparison with standards.

Control of material is exercised through the manufacturing layout previously described, which determines the amount of raw material that shall be withdrawn from stock for the manufacture of each part.

The overhead or loading factor in costs is expense, and our control over expense is accomplished through the use of a budget.

Manufacturing expense includes depreciation, taxes, insurance, non-productive pay, changes repairs, supplies, and miscellaneous expense not directly assessable against definite jobs but common to all or a number of jobs.

Expense is distributed into the cost of the product by means of loading rates, and it is essential that this element of cost be definitely controlled through some means which will insure a proper cost-level trend. For the purpose of control, a detailed departmental budget is used.

The budget is a prediction regarding future events based on the

results of the past. It is the setting up of a definite objective for factory operation. Our departmental budget system, set up by expense classifications, definitely places functional responsibility for expenditure. The budget plan recognizes two fundamental principles. The first is that fluctuations in factory load necessitate the expenditure of varying amounts for expense. The budget, therefore, should be determined to allow for fluctuations in expenditure as a result of variations in factory load. For this purpose our budget is divided in detail into a constant and variable portion, the constant portion representing the amount of expense which will not vary with activity or volume of business; the variable portion being that expense which will, under ordinary circumstances, vary directly with activity. Second, our budget plan recognizes the fundamental principle that expense must be charged to the department which approves the expenditure. This fact furnishes the dynamics which make the budget effective.

The budget is operated by setting up a normal budget divided between constant and variable, which represents the amount of expense required to operate the factory at a theoretical 100 per cent activity. The actual budget allowed is the constant portion of the budget at 100 per cent activity, plus the variable portion increased or decreased by the percentage of normal activity actually realized in shop operation. The percentage used is the relation of the loading returns from current production to the normal loading returns at 100 per cent activity. The reason that loading return is used in determining shop activity in connection with budget control is that loading represents expense, and as the expense varies with shop work, so should the expense budget allowance vary.

Realization budget reports are prepared in detail, and also by main organization units and main classifications of expense. A sample of the latter is illustrated in Fig. 13. These are distributed throughout the organization to the lowest unit for which a budget has been set. Competitive reports also are issued as illustrated in Fig. 14.

It is especially necessary to discover the exact cause of failure to meet the budget, and to record such facts so that they may be properly used in determining the budget for the following period. It is desired that the budget become a goal for which rank-and-file supervisors, as well as the higher executives, will aim with full assurance that the goal is a fair one if constant attention is directed toward expense control.

The benefits obtained from the use of this type of expense budget are as follows:

1 The confidence of the supervisors throughout the organization that the budget is a fair measuring stick for performance, as it varies with activity and recognizes responsibility for expenditures.

2 More economical operation of the factory is obtained through the study of expenses in advance and setting up a definite program for expenditure consistent with the volume of business.

3 It avoids the possibility of any one portion of the organization destroying the profits of another portion through unauthorized expenditure.

4 Every unit of the organization is given a definite goal for attainment.

To avoid the use of detailed product costs as a measure of performance, but rather overall trends in cost levels, we have developed a fundamental plan for obtaining costs which, we believe, is somewhat unique although economically sound. Our cost system is set up so that expenditures inherent in an article are associated directly with the cost of that article, and form what is known in our nomenclature as the basic cost; while expenditures common to a group of articles of the same general class, such as extra cost of overtime, higher cost due to less experienced operators, etc., are prorated over the individual basic costs.

This is accomplished by means of blanket orders which are arranged by classes of work, in line with the functionalized scheme of organization of the operating departments. The cost of work is figured weekly, monthly, quarterly, and semiannually, and all labor, material, and loading for each class of work is charged to a blanket order.

The total output of each item manufactured on each blanket order is evaluated at basic labor and loading costs which are set up from predetermined fundamental data. The ratio of the total actual charges to the total basic cost is determined, and this ratio is applied to the total basic cost of each item. By this means we obtain costs which include their pro rata share of excess costs

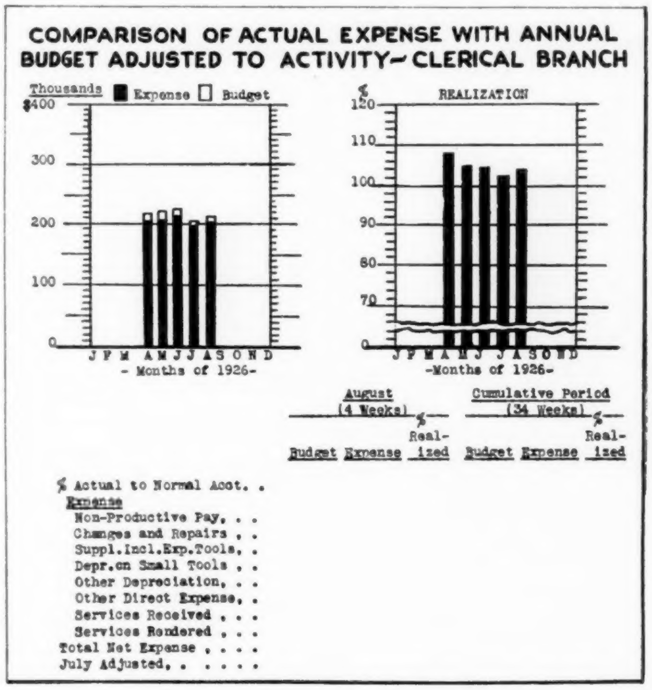
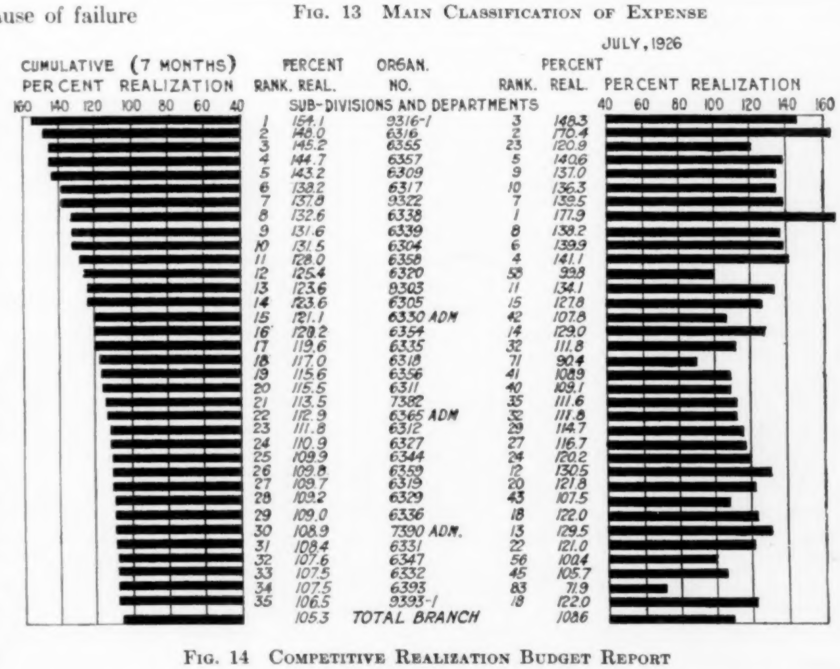


FIG. 13 MAIN CLASSIFICATION OF EXPENSE



RANK.	PERCENT REAL. (Cumulative)	ORGAN. NO.	RANK.	PERCENT REAL. (July, 1926)
1	154.1	9316-1	3	148.3
2	148.0	6316	2	170.4
3	145.2	6355	23	120.9
4	144.7	6357	5	140.6
5	143.2	6309	9	137.0
6	138.2	6317	10	136.3
7	137.8	9322	7	139.5
8	132.6	6338	1	177.9
9	131.6	6339	8	138.2
10	131.5	6304	6	139.9
11	128.0	6358	4	141.1
12	125.4	6320	58	99.8
13	123.6	8303	11	134.1
14	123.6	6305	15	127.8
15	121.1	6330 ADM	42	107.8
16	120.2	6354	14	129.0
17	119.6	6335	32	111.8
18	117.0	6318	71	90.4
19	115.6	6356	41	108.9
20	115.5	6311	40	109.1
21	113.5	7382	35	111.6
22	112.9	6365 ADM	32	111.8
23	111.8	6312	29	114.7
24	110.9	6327	27	116.7
25	109.9	6344	24	120.2
26	109.8	6359	12	130.5
27	109.7	6319	20	121.8
28	109.2	6329	43	107.5
29	109.0	6336	18	122.0
30	108.9	7390 ADM.	13	129.5
31	108.4	6331	22	121.0
32	107.6	6347	56	100.4
33	107.5	6332	45	105.7
34	107.5	6393	83	71.9
35	106.5	9393-1	18	122.0
	105.3	TOTAL BRANCH		108.6

FIG. 14 COMPETITIVE REALIZATION BUDGET REPORT

for such items as overtime, defectives, etc., and are nearer "actual" than the so-called actual costs determined by a definite order scheme.

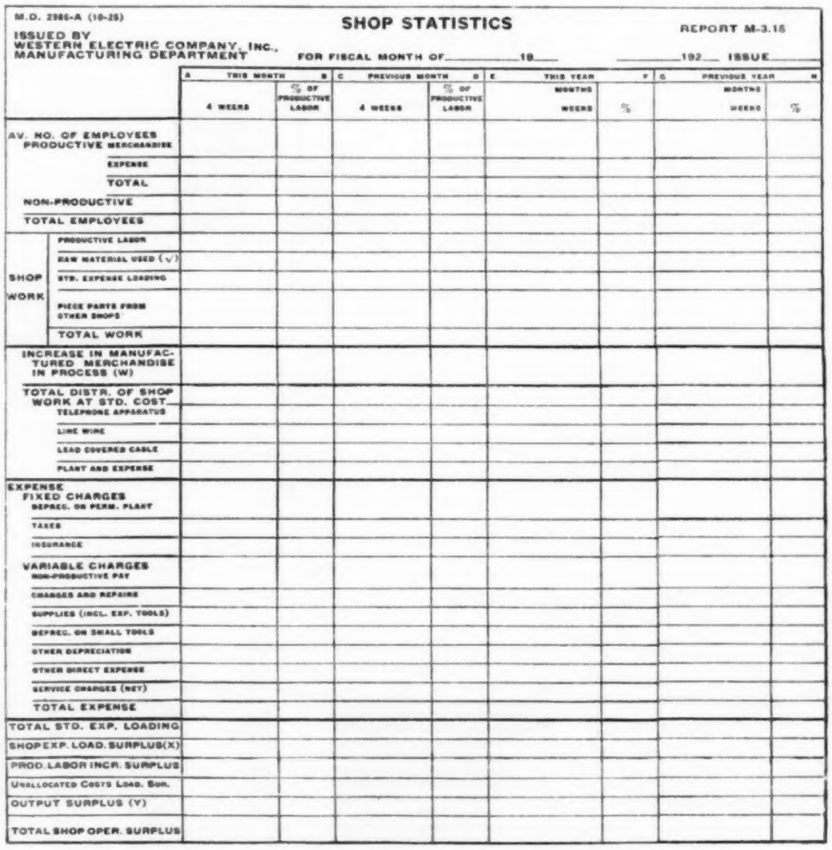
As a further means for the control of costs, outputs on each blanket order are priced and summarized quarterly at a record cost for a previous period and compared with the actual cost as shown on the blanket order for the period covered by the output. Studies of such statistics present a picture of manufacturing difficulties or inefficiencies; they show on what product they exist, and in what part of the organization, and help to determine the necessary steps to be taken to eliminate the causes of the

trouble. A summary of blanket-order actual costs and record costs is also compiled quarterly. This compilation shows the general cost trend and is used for predicting operating results for the year.

Results

The means of control of many of the functions of greater importance in our Manufacturing Department have been described. Of course, in addition to these there is a vast volume of detailed controls of more or less importance which time precludes setting forth in this paper. In closing, however, it is well to round out the presentation with a description of a series of reports which bring together the results of these diversified efforts so that a complete picture of operating results is obtained. The management must know the expenditures for labor and material, and the results which have come from those expenditures. It must be enabled to visualize how the expense money spent compares with the returns for that expenditure. It must know also the result of comparison of the total actual costs of all products with the corresponding standard costs set up for billing the factory product into the Merchandise or Sales Account. And finally, the management must also have a means of comparing the operation of the current month with the preceding one, and of seeing how the cumulative results for the year compare with the same period for the previous year.

Such a picture is obtained from several reports which we call the Shop Statistics Reports, which, in order to explain their control features, must be considered as a group.



M.D. 2986-A (10-25) SHOP STATISTICS REPORT M-3.15

ISSUED BY WESTERN ELECTRIC COMPANY, INC., MANUFACTURING DEPARTMENT FOR FISCAL MONTH OF ______ 19___ ______ 192___ ISSUE ______

	A This Month: 4 Weeks	B % of Productive Labor	C Previous Month: 4 Weeks	D % of Productive Labor	E This Year: Months / Weeks	F %	G Previous Year: Months / Weeks	H %
Av. No. of Employees — Productive Merchandise								
Expense								
Total								
Non-Productive								
Total Employees								
Shop Work — Productive Labor								
Raw Material Used (√)								
Std. Expense Loading								
Piece Parts from Other Shops								
Total Work								
Increase in Manufactured Merchandise in Process (W)								
Total Distr. of Shop Work at Std. Cost — Telephone Apparatus								
Line Wire								
Lead Covered Cable								
Plant and Expense								
Expense — Fixed Charges — Deprec. on Perm. Plant								
Taxes								
Insurance								
Variable Charges — Non-Productive Pay								
Changes and Repairs								
Supplies (Incl. Exp. Tools)								
Deprec. on Small Tools								
Other Depreciation								
Other Direct Expense								
Service Charges (Net)								
Total Expense								
Total Std. Exp. Loading								
Shop Exp. Load. Surplus (X)								
Prod. Labor Incr. Surplus								
Unallocated Costs Load. Sur.								
Output Surplus (Y)								
Total Shop Oper. Surplus								

FIG. 15 SHOP STATISTICS REPORT

The Shop Statistics Report group is made up of three reports: an annual Budget of Shop Statistics, issued on December 1 for the ensuing year; a Shop Statistics Report, issued monthly, showing actual results for the month and cumulative for the year, and a Forecast of Shop Statistics, issued three times a year and based on figures available at the end of April, July, and October.

In the Budget of Shop Statistics Report the expected output for the coming year is shown by main groups of product and is also broken down into its elements: labor, material, expense, increase or decrease in shop inventories of completed or partially completed parts, and shop surplus. These factors are determined from a consideration of the actual results for the first nine or ten months of the current year, adjusted for any known changes in conditions which will become effective in the ensuing year.

The Shop Statistics Report, issued monthly, shown in Fig. 15, shows for the month just closed, actual labor, raw material, and purchased piece parts used, expense, output, changes in process inventories, loading returns, and shop surplus or deficit divided between that in output, in loadings, and in labor increment. Each of these figures is given for the current month, the previous month, and for the year to date. This permits direct comparison of the current month's figures with those for the earlier months and shows whether our shop work, output, and shop surplus are on the upgrade or on the decline. It also shows whether the relationship of each cost factor to total shop work remains constant and whether our expense as compared with loading returns is increasing or decreasing. Productive labor is used as a base and all figures show the percentage relation to it.

The Forecast of Shop Statistics Report combines a survey of the past with a look into the future. The items covered in this report are identical with those covered in the annual and monthly reports, but the figures shown are cumulative for the year to date. This report also gives the forecast for the remainder of the year, and a comparison of the sum of those two with the corresponding Budget of Shop Statistics figures. The cumulative figures are taken from the monthly report, and the forecast is worked up in the same way as the budget, except that our latest estimate of output is used as a basis, and the trend of shop surplus is determined by a study of the actual to date. This report possesses valuable control features. The comparison of present view for the year with budget output, for instance, shows the management whether the shop activity is at the proper level and gives early warning of any danger of over or under production. The estimated labor for the remainder of the year, divided by the average rate of pay per employee, shows what changes must be made in present personnel in order to meet the requirements of the manufacturing program. The expected expense surplus or deficit for the year compared with the budget figure notifies the management when curtailment of expense is necessary. The expected change in inventory provides a safeguard against the possibility of overloaded stock shelves at the end of the year, thereby maintaining the proper investment. And, finally, the surplus or deficit estimated for the year in the Output Account provides the management with an overall index of the cost level obtaining during the current month and year, with the output cost of the product used in billing the Merchandise Account. The output cost being largely the cost of the preceding year, this figure is the index of the relative efficiency of shop operation for the current year compared with the previous year.

Conclusion

This paper has described in a general way, how the Manufacturing Department of the Western Electric Company functions in the control of production. Without the inclusion of too many details, an attempt has been made to show some of the problems encountered in meeting the changing and increasing demands of a business which requires a great volume and variety of product. The growth of our present organization has been a gradual process of continuous development since the inception of the telephone industry. The methods evolved, while applicable in the main to general manufacture, have of course been developed to meet our own particular needs.

Discussion

Robert T. Kent,[2] who opened the discussion, said that the main thing that struck him in reading over the author's paper was the fact that it bore out in the practice of a large corporation so many of the fundamental principles that were laid down by Taylor in his original presentation of shop management.

The author stressed the importance of scheduling, and in the paragraph entitled "The Forward Picture" he summed up the whole matter. Unless one had a vision of what he wanted to do and how to do it, all the routine, all the schemes, all the forms in the world would not give good management.

It was of small importance what particular set of forms and what routine were adopted. The routine the author had described probably would not work in any other company than the Western Electric Company. The method of management, the details that were applicable to one company, probably would prove fatal to another.

The work in which Mr. Kent was engaged, he said, involved the operations of seventeen different industries of very diverse character. A rather well-considered scheme of management had been laid out, but it had been found that the details of its application had to be varied for every different industry. The thing to do in developing any production control was to study the problem, get the vision as the author had outlined in his remarks on the "forward picture," and then work each industry with a view to the problems of that industry and without any attempt to make a blind copy of what some one else had done.

Percy Brown[3] said that it had not been generally recognized that the management philosophy of the Western Electric Company was fundamentally sound and not new. From personal experience at the works he could testify that as far back as 1905 their methods of determining piece rates had been sound, and he knew that the staff had been avid readers of the works of Frederick Taylor as they had come out. The author's work as described in the paper, Mr. Brown said, was an example of the engineering approach to the problems of production, and he wanted to express personally his appreciation from the standpoint of one interested in scientific management that the Western Electric Company had come out with this example of their work, and he hoped it was merely the forerunner of detailed statements of their technique and of the vital and interesting problems they had solved.

C. M. Ford[4] said that concerning the division of stock groups he had understood the author to say that he intended to locate the stores or stock-rooms as near as possible to the point of consumption of the materials controlled in them. He desired to learn just how far the author intended to go in that direction and not lose advantage of a general or centralized control of a storeroom, for the latter could not be split up.

The author, replying to Mr. Ford, said that it was necessary to draw the balance in the illustration given in the paper. The manufacturing or plan layout had been worked out to fit the particular conditions. Heavy materials had to be stored on the ground floor, and an endeavor was made to place the departments using them on the ground floor as far as possible. In almost all cases the location of storerooms was largely a matter of compromise, to fit various conditions. In the assembly where the loads were light the storerooms were arranged on the top floors adjacent to the assembly departments, there being usually a part storeroom between every two assembly departments.

[2] Superintendent, Prison Industries, State of New York, New York City. Mem. A.S.M.E.

[3] Brass Goods Mfg. Co., Bridgeport, Conn. Assoc-Mem. A.S.M.E.

[4] Powers Paper Co., Springfield, Mass.

The Engineer in the Retail Store

Department stores require engineering ability whether they realize it or not. The real need is for a man with a keen, technical, analytical mind, a sound economic foundation, a highly developed sense of observation, and a pleasing personality.

Some of the operations in department stores which make retailing a fertile field for engineering ability are as follows:

Delivery includes the auto station's function and operation of fleets of trucks varying in size from 3 to 300. The shipping room or the internal delivery department often utilizes many belt conveyors for sorting and routing packages. The actions of people must be coördinated with the operation of production machinery. Time and motion studies of the various operations can be used to decrease delivery costs.

The best methods of handling bulky and fragile merchandise is a problem involving transportation, personnel, wrapping and packing, and training. The automotive engineer with production and industrial experience or the industrial engineer with automotive experience is admirably fitted to supervise delivery operations.

Receiving and Marking embraces the handling of goods between common carriers and stock rooms. In this process the merchandise must be transported, received, checked, inspected, and marked. Motor trucks, automatic marking machinery, personnel production, systematic handling, and an endless amount of system are involved. Methods must be evolved to protect the goods from being damaged or stolen. Quick and orderly handling must insure the goods' being moved to their final destination with the least amount of delay. A knowledge of the working principles of the industrial engineer is an asset to the man in charge of this section.

Work Rooms present industrial problems of shop layout and system, personnel relations, and time and motion studies.

Building Maintenance includes the care of the store (not merchandise), economical window washing, general cleaning of floors and walls, painting, building construction, heating, lighting, rubbish disposal, and the maintenance of elevators, belt conveyors, escalators, heating and ventilating plants, etc. Several stores having capable engineers on their staffs state they make changes in their elevator and belt-conveyor systems more cheaply than the same work could be done by the manufacturers of the equipment. Some stores find it economical to build some of their own fixtures.

New Construction. It is necessary to employ engineers and architects to plan and build new structures. Outside consultants rarely have an intimate knowledge of specific department-store problems. They could not be expected to have a large fund of retailing experience. Furthermore all the facts concerning retail operations cannot be acquired within a short period of time.

Store owners who have had people with engineering training in their employ for some time previous to the starting of new construction have found that they saved money in various phases of the project. Blueprints were examined more carefully to save every available square foot of space. There are always corners and hidden cubical spaces which are often not utilized by the outside expert. Various service departments, offices, etc., can be located in them and the more open areas saved for selling. Since the main function of the store is to sell goods, it very often happens that the new structure is designed only for selling, and too little attention is given to getting merchandise in and out.

It is difficult for the engineer who does not understand department-store operating conditions to avoid making these mistakes. Finally, there is an endless amount of checking of plans and blueprints, the letting of contracts, decisions to make regarding whether or not to excavate more or less of a basement. Such work should be done by people who understand it.

Wrapping and Packing involve time and motion studies, layout and equipment, use of proper materials, bonus systems, and many other such details necessary to getting the merchandise prepared for delivery at a minimum cost. Sometimes the use of mechanical belt conveyors is advisable. There are many fundamental principles in good engineering practice which, if applied in wrapping and packing departments, would increase production and lower costs.

In general, compensation in the retail field is as high and often higher than in industrial plants, because more than pure engineering knowledge is required of the individual.—A. W. Einstein, Manager, Retail Delivery Association, in *The Bulletin* of the National Retail Dry Goods Association, November, 1926, p. 30.

Relation of Stokers to Boilers

Early Attempts to Improve Combustion—Heat-Absorbing Surfaces—Per Cent of Rating—Operating Difficulties—Selecting the Correct Boiler and Stoker for a Given Condition

By W. A. Shoudy,[1] New York, N. Y.

Apparatus for the mechanical feeding of coal to a boiler furnace was developed primarily for the purpose of reducing human labor. Such appliances were called "mechanical" stokers to distinguish them from "human" stokers. The reduction of labor was not so great as expected until coal-conveying apparatus replaced the coal passer, but the mechanical stoker gradually gained popularity because, by the elimination of frequent opening of the fire doors, excess air was reduced and furnace efficiency increased. In common parlance, the boiler efficiency was improved, although the boiler had nothing to do with the improvement.

Early Attempts to Improve Combustion

By the use of forced draft, combustion rates of 40 lb. of coal per sq. ft. of grate surface could be obtained for short periods with hand-fired grates when the super-fireman could be found who could handle so large a quantity of coal. When the chimneys were high enough such combustion rates meant a horsepower output 25 or 30 per cent in excess of the boiler's rated capacity.

The rapid building-up of the fuel bed and the necessity for more frequent cleaning of fires limited such runs to a very few hours. The use of rocking or dumping grates helped the cleaning problem, but only slightly reduced the manual labor.

The application of forced draft to the chain-grate stoker and the development of the underfeed stoker and its operation with forced draft made continuous operation possible at these higher rates of combustion, because the extraordinary human effort was eliminated and cleaning of fires could be carried on without serious interruption to service.

The length of the grate was no longer limited by the distance that a man could throw coal with a shovel, hence stoker grates were soon extended beyond the length of the flat grate and a larger total weight of coal could be burned without increasing the rate of combustion per square foot of grate surface. More careful design of the stoker grate so as to get a more uniform distribution of coal in the fire bed and improvement in combustion-air distribution resulted in increased rates of combustion without sacrifice of furnace efficiency but rather, in most cases, an actual improvement. This increased liberation of B.t.u. per sq. ft. of grate was delivered to the boiler heating surface and evaporated a larger quantity of water, and the era of high ratings began.

Since the heat-absorbing surface (the boiler surface) was not increased, higher rates of transmission were necessary and were obtained, but at the cost of increasing exit gas temperatures, i.e., at a reduction of heating-surface efficiency. However, boiler tests showed in many cases an improved combined boiler and furnace efficiency. It should be obvious that this improvement was due to improved furnace efficiency.

Heat-Absorbing Surfaces

The increasing length of stokers rapidly pushed back the bridge-wall until it became the rear wall of the boiler setting. The tubes were then lengthened to give a larger heat-absorbing surface, and the stoker was again lengthened to meet the longer tubes. With such combinations, operation at ratings of 300 per cent was not unusual. These high ratings were obtained at a sacrifice of combined efficiency, because of the higher exit gas temperature. Additional heat-absorbing surface was added as economizer or air-heater surface, which increased the combined efficiency without altering the combustion efficiency or boiler efficiency per se.

More boiler surface was next added by increasing the height of the boiler, thus reducing the work of the economizer or air heater, and in some cases eliminating them where the highest combined efficiency was not justified by use factor or fuel cost.

For many years the preponderance of inclined straight-tube boilers were built with 14 tubes counted vertically. Additional surface was obtained by increasing the number of tubes vertically. This gave a cheaper boiler per square foot of surface, but no larger stoker could be fitted under it than under a 14-high boiler. Consequently no higher horsepower or steam output could be developed, nor could the stoker be operated at a higher rate of combustion or higher furnace efficiency. Because the heating surface was larger, the exit gas temperatures were lower; hence the combined efficiency of the higher boiler exceeded that for the 14-high boiler for the same steam output.

The 20-high boiler or its equivalent is quite common, and a few 24 tubes high have been in operation for a sufficient time to prove their worth. A boiler with 4-in., 20-ft. tubes and 18 tubes wide will have a heating surface, depending upon the number of tubes high, approximately as follows: 14-high, 6200 sq. ft.; 20-high, 8400 sq. ft.; and 24-high, 10,000 sq. ft. The same size of stoker will fit under each of these boilers because the floor space is the same. If, therefore, a stoker is selected for the first boiler which will permit of operation at 400 per cent of rating, 2480 hp. will be developed. If the first boiler is replaced by the 20-high and neither the coal nor the stoker is changed, no greater output can be obtained, and the maximum rating for this combination will be 295 per cent. If the 24-high is next substituted, only 248 per cent of rating can be obtained. Since the furnace conditions are the same in all three installations, the furnace efficiency will be the same for all, but the combined efficiency will be the highest with the 24-high installation. The heat liberated by the stoker is the same for all three, but the 24-high boiler presents a larger heat-absorbing surface and a lower exit gas temperature. If a larger stoker is installed with the larger boiler, it might be operated at 300 per cent of rating, developing 3000 hp.; however, that same stoker under a 14-high boiler would deliver the same horsepower, but the boiler would operate at 485 per cent of rating.

Per Cent of Rating

The term "per cent of rating," where applied to present-day boiler operation, is of little value and at times is even misleading unless the design of the boiler is specified. This is particularly true, for example, when comparison of the reports of the Hell Gate boilers and those of the new Interborough boilers is attempted. The last Hell Gate boiler is a 3-in.-tube boiler whose surface approximates a 12-high, 4-in-tube boiler. The Interborough boiler is 24 tubes high. The ratio of heating to grate surface in the latter is therefore approximately double that of the former if the same stoker is used. The tests reported by Mr. Reynolds, showing 343 per cent of rating, represent a furnace condition approximating 686 per cent of rating on the Hell Gate boilers; whereas the highest reported rating on these boilers, 590 per cent (*Power*), is the equivalent of 295 per cent of rating on the Interborough boiler.

This comparison is not made for the purpose of drawing any conclusion as to the relative merits of the two installations, but merely to show of how little value are comparisons on the basis of per cent of rating. Intelligent comparison can be made between such widely separated installations by comparison of the stokers on the basis of pounds of coal or B.t.u. liberated per square foot of grate area (actual or projected), and the boilers on the basis of evaporation per square foot of heating surface or per foot front of boiler furnace. Until some one can develop an all-inclusive term, we must make our comparison on such a basis. The author hopes that the term "per cent of rating" may be eliminated from the steam engineer's vocabulary.

In stationary practice we have not reached the limit of evapora-

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tion for the steam boiler. This is shown by the higher ratios obtained in marine boilers. If the boiler feedwater is good and the boiler design such as to provide satisfactory circulation, there are apparently only minor operating difficulties experienced when operating boilers at high rates of evaporation.

It is nevertheless common to hear of interruptions to service due to operation at "high ratings." This is so much the case that "high ratings" have been left to the central station, and the industrial plant has generally kept to conservative operation. These ratings have not always been as conservative as the purchaser has expected. Because of the fact that 14-high boilers have been successfully operated in industrial plants at 200 per cent of rating, 20-high boilers have been installed for the same rating, yet the latter furnace condition is the same as for a 14-high boiler at 275 per cent of rating. Unless the stoker and furnace are carefully selected for the high boiler, trouble may be expected; but not with the boiler.

Operating Difficulties

Operating difficulties at high ratings are due to one or more of the following causes:

1 Impure feedwater
2 Poor circulation, or insufficient steam liberating surface
3 Restricted feedwater supply
4 Grate or stoker trouble
5 Ash or clinker trouble
6 Refractory trouble.

The first three can be foreseen and any one of them eliminated before it occurs, or the boiler installations must be limited to conservative rates of evaporation. The last three, or furnace troubles, cannot always be foreseen and are less easy to prevent, but they can be minimized by careful engineering. They all vary with the coal and are so interrelated that they cannot always be separated and studied. Perhaps the major difficulty is with the impurities in the coal.

Operating difficulties almost never occur at low combustion rates. The rate at which trouble begins is almost invariably determined by the impurities in the coal. Before the type of stoker can be selected the character of the coal must be known, as follows:

1 The relative ease of ignition
2 The percentage of ash content
3 The fusion temperature of the ash.

Each of these divisions may be subdivided still further, although this is generally unnecessary.

Anthracite is hard to ignite and its combustion is difficult to maintain. The finer sizes can best be burned in thin fires and when not agitated. The chain grate makes possible a thin fire without agitation as well as a continuous dump for the relatively larger ash content, and refractory arches for maintaining ignition can be installed without great difficulty.

Coke breeze offers generally the same difficulties, although some qualities have been burned successfully on underfeed stokers; in general, however, both of these fuels are best adapted to the chain grate.

The eastern bituminous coals, with their higher volatile content and generally low ash, seem to have been created for the underfeed stoker. The fusing temperature of the ash is generally above 2400 deg. fahr., offering little clinkering trouble, and the highest combustion rates are easily obtained.

As we move westward into the fields of higher ash content and lower ash-fusion temperatures, the underfeed-stoker troubles begin. The continuous ash discharge or clinker grinder must be substituted for the dump plate because of the larger quantities of ash that must be removed, and a lower rate of combustion must be selected so that the fire-bed temperature may not be sufficient to fuse the ash and cause clinker trouble. The chain grate is an active competitor in these territories because of its continuous dumping action and the generally lower rate of combustion and thinner fire.

The sub-bituminous and lignite fields are still any one's territory, although pulverized coal at present seems to offer the best solution to this problem.

Another ash trouble is that due to the molten fly-ash which passes in to the boiler surface, adhering to the tubes and restricting the gas passages. This trouble varies with the coal and the rate of combustion. The lower rates of combustion apparently do not cause a sufficiently high gas velocity to carry the slag into the tube space. The front headers of some boilers have been raised 21 ft. above the boiler-room floor without completely remedying the trouble. Some improvement has been accomplished by leaving out alternate tubes in the lowest row or rows, thus eliminating bridging from tube to tube. Some of this fly-ash on reaching the colder space between the tubes is chilled and drops back into the furnace or passes through the boiler as hard ash. Preheated combustion air has helped in some cases and not in others. Some time must elapse before definite conclusions can be drawn as to this action.

For many years refractory failures were laid to too low a grade of firebrick or too high a furnace temperature, but it has become common knowledge that the chemical composition of the ash is just as large a factor in furnace design. Much of the erosion of the firebrick can be laid to the fluxing action of the molten ashes, especially those of low fusing temperature. Brick that will successfully perform with one coal will not do so with another because molten fly-ash washes away the brick until the wall fails or a state of equilibrium is reached when the heat radiated from the brick is sufficient to cool the surface to the congealing temperature of the ash. This trouble is more pronounced with pulverized coal than with stokers. The solution seems to lie in cooling the wall either by air or by water. The reduction in rate of combustion, that is, larger stokers or more of them, helps with some coals if the action is not severe.

Spalling is not always due to poor brick. Clinker adhering to the walls has a larger rate of contraction than the brick. On cooling the clinker shrinks and shears off the surface, leaving the brick with the appearance of having spalled.

Although these troubles are generally recognized, they have been mentioned because they emphasize the fact that furnace and stoker troubles are functions of the fuel quality and the rate of combustion. "High ratings" are therefore limited by these two factors.

Selecting the Correct Boiler and Stoker

The problem of selecting the correct boiler and stoker combination becomes one of selecting first the stoker and furnace and then selecting the best heat-absorbing surface that price of fuel, draft, use factor, and fixed charges will permit. The heat-absorbing surface will be the boiler alone or with economizer and air heater, or with either.

The size of the stoker will depend upon the quality of the coal and whether or not money can be spent for water- or air-cooled walls. It is doubtful whether water-cooled walls can be justified for boilers smaller then 750 hp., except possibly a patch at the base of the bridgewall or when the fluxing of the ash is unusually severe. Without water cooling, 60 lb. of coal per sq. ft. of projected grate area should be the maximum for underfeed stokers. With complete cooling, 75 lb. may be used; but in either case 35 to 50 lb. should be the rate for best operation. Preheated air may improve these rates, though complete data are lacking, and higher rates cannot be counted upon at present. We must content ourselves with the heat saving by the preheater and the better behavior of the fuel with preheat.

With anthracite 55 to 60 lb. should be considered a maximum, and the best rates taken as 30 to 45 lb. The higher rates will give capacity, but at the expense of loss of fine coal to the chimney.

It is impossible to completely catalog all fuels. Before selecting a stoker the behavior of the local coal should be observed on another installation, the correct rate of combustion selected, and the stoker proportioned accordingly.

For the purpose of illustrating the folly of selecting boilers solely on the basis of their respective performances at "per cent of rating," the author has included a brief study of boiler and stoker combinations for a plant to deliver 300,000 lb. of steam per hour from and at 212 deg. fahr. He has estimated the efficiencies of six different boiler and stoker combinations. In order that these efficiencies may be strictly comparable he has assumed one type of stoker, namely, the multiple-retort underfeed stoker, provided with rotary ash discharge or clinker grinder. He has assumed a coal of 14,000 B.t.u. dry basis with 7 per cent ash.

It is impossible to plot a curve of furnace efficiency, but the

efficiency of the stoker can be indicated very clearly by the per cent of CO_2 and the per cent of carbon going out in the refuse. These assumptions are plotted as curves in Fig. 1. With low rates of combustion it is difficult to maintain low excess air, but at the higher rates a uniform per cent of excess air can be maintained with reasonably careful operation. The excess-air loss is therefore high at low rates of combustion. As the rate of combustion increases it becomes increasingly difficult to keep down the per cent of carbon going out with the ash. The efficiency of the stoker is therefore low at low rates of combustion and at extreme rates of combustion, but reasonably flat over the intermediate rates. The assumed per cent of carbon in the refuse may be criticized as being too low. It does not represent past practice, but the author

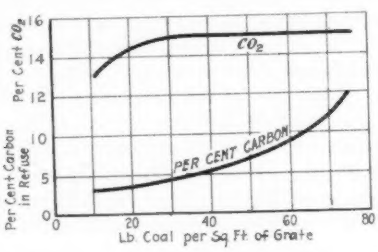


FIG. 1

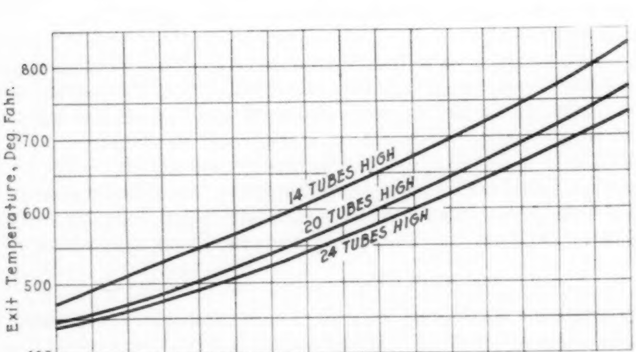


FIG. 2

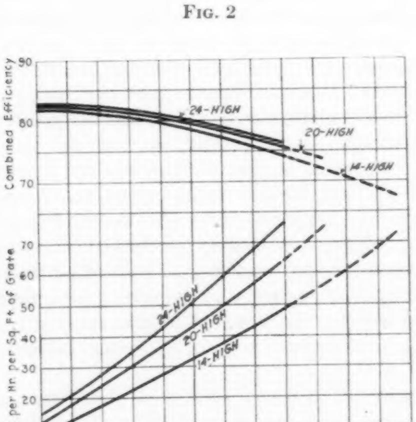


FIG. 3

believes it represents what can be expected of a modern underfeed stoker.

Three types of boilers have been assumed, but all of them have the same furnace width and length. They are as follows:

1—620 hp., 14 tubes high
2—840 hp., 20 tubes high
3—1000 hp., 24 tubes high.

All of these boilers are 18 tubes wide and the tubes are 20 ft. long. The expected exit gas temperatures are plotted in Fig. 2. For the purpose of simplicity, as well as to obtain a more accurate comparison, all losses listed in the boiler heat balance are assumed constant at all outputs except the losses due to carbon in the refuse and chimney losses.

The first comparison is made with each of these boilers equipped with a six-retort underfeed stoker with a projected grate area of 206 sq. ft. The efficiencies of these three boilers and the same stoker are plotted in Fig. 3 against "per cent of rating." The rate

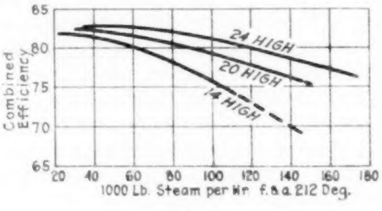


FIG. 4

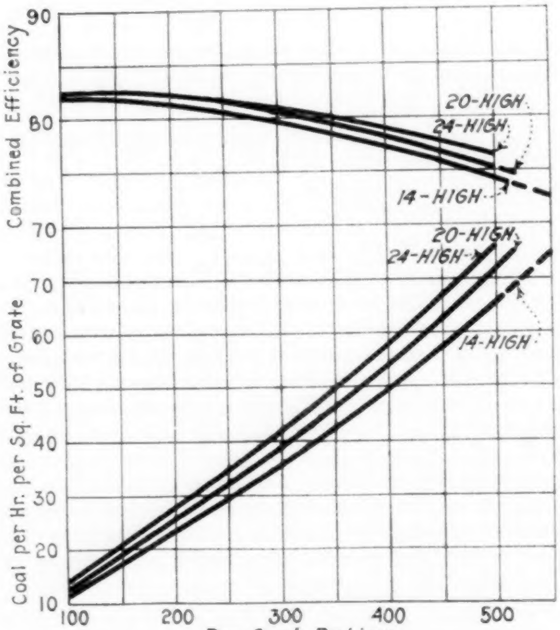


FIG. 5

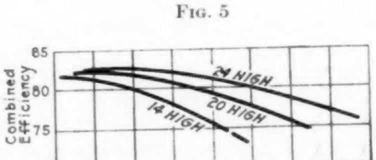


FIG. 6

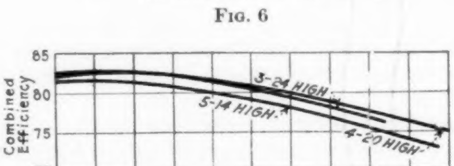


FIG. 7

of combustion for each combination is also plotted. With the continuous dump or clinker grinder and rather complete water cooling of side walls, a maximum combustion rate of 75 lb. per sq. ft. of projected area may be expected. Under such conditions the 14-high boiler would deliver 640 per cent of rating; the 20-high, 540 per cent of rating; and the 24-high, 490 per cent of rating. With water-cooled walls we should not expect stoker troubles at these high rates because of the large size of stoker. We can, however, expect boiler troubles unless provision is made for a high rate of feed to the boiler as well as abundant steam-liberating surface. Such boilers would also have to be operated with only the purest feedwater. Inasmuch as the assumed plant is of a relatively small size, it would hardly seem advisable to go to the expense of water cooling, in which case

the rate of combustion might be kept to 60 lb. as a maximum with proportionately lower "per cent of rating." The per cent of rating mentioned above, of course, applies only to short periods. The continuous maximum rate should be limited to about 50 to 55 lb. per sq. ft.

In Fig. 4 these combined efficiencies have been replotted against steam output of boiler instead of rating. The curves as plotted in Fig. 3 show very little difference in efficiency, but when replotted in Fig. 4 the differences are so apparent as to need no further discussion. The selection of the boiler therefore becomes merely a matter of determining whether the reduction in fuel per year will offset the increased fixed charges of the larger boilers.

Combined Efficiencies for Various Boiler and Stoker Combinations

Variations in plant loading throughout the year often require a larger number of boilers than the three mentioned above. The combined efficiencies have therefore been worked out for a plant with three, four, and five boilers, respectively. Inasmuch as stokers are made in standard sizes, it is impracticable to get a combination with which there will be exactly the same proportion of heating surface and grate surface. The proportion is indicated by the following statement:

Boilers	Stokers
3—1000 hp., 3000 hp. total	3—206 sq. ft., 618 sq. ft. total
4— 840 hp., 3360 hp. total	4—184 sq. ft., 736 sq. ft. total
5— 620 hp., 3100 hp. total	5—152 sq. ft., 760 sq. ft. total

The boilers are respectively 14 high, 20 high, and 24 high. The combined efficiencies of these combinations have been plotted against rating in Fig. 5 and are replotted against steam output per boiler in Fig. 6. Fig. 6 also indicates that the 24-high boiler is the best selection. However, when these efficiencies are again plotted, but this time against the total plant output, the 20-high boiler is seen to be the equal of the 24-high, and the 14-high is only one point lower than either.

The reason for this condition is obvious when we note the total horsepower installed. Case 1 has the smallest total horsepower and the largest boilers; case 3 has the next largest horsepower, but the smallest boilers and the largest grate area; case 2 has the largest horsepower and the middle-size boilers; consequently, case 1 operates at the highest rating, case 3 at the intermediate rating, and case 2 at the lowest rating. The lower rating of case 2 offsets the lower exit temperature expected with the higher boiler, and case 3 has slightly lower efficiency, because the 14-high type of boiler has a higher exit temperature than the 20-high for the same rating.

A large number of other combinations might be worked out. If high overloads are not expected at this plant, slightly smaller stokers might be selected. Narrow, but longer, stokers might be installed in a five-boiler plant, using a higher boiler to get the same surface. This would work out a little more efficiently than the case selected. The exact answer cannot be worked out in such a way that it will apply to all boiler houses. The five-boiler combination would, of course, be the most expensive. There would be five settings to erect instead of three. The boilers and stokers would cost approximately the same, but the boiler house would be longer, greatly increasing the cost of the project. The determination of the number of units would be settled, not by a comparison of boiler efficiency but by a comparison of the total cost of the project and by local conditions governing the number of boilers.

Basis of Selection

Enough data have been presented to show that the selection of the correct combination of stoker and boiler cannot be determined by rule-of-thumb methods, nor can it be based upon comparisons of operation at certain percentages of rating. The selection must be made in the following manner:

1 Determine the number of boilers that the variations in load and local conditions demand

2 Select a grate surface of sufficient size to permit of conservative combustion rates

3 Determine the rate of evaporation that feedwater conditions will permit

4 Select the most efficient heating surface that draft, coal costs, and fixed charges will permit.

Discussion

In a written discussion of the paper, W. H. Jacobi[2] expressed pleasure at the gradually increasing tendency to designate boiler capacity in terms of pounds of steam produced or of water evaporated, rather than to use the terms "boiler horsepower," "per cent of rating," and "factor of evaporation," which he classed as meaningless and misleading. He hoped that the next step would bring a suitable "unit of evaporation," which would encompass all the conditions leading to a comprehensive and profitable boiler operation.

Continuing, he said that no subject merited greater attention than the development of a comprehensive set of rulings or definitions to designate the performance of a boiler, its possibilities and its limitations. Not only was this necessary to foster the achievement zealously wrought in recent times, but to enlighten the way toward a sound understanding of the functions of boilers with relation to those of the fire which was at the base of this performance. He felt that much had been said which ought never have been said, and too little of the things we ought to know. He urged the formulation by the Society of a code defining the functions of each constructive part and the requirements of a boiler installation as a whole to secure the best results. Such a code, he said, should be of inestimable value in checking the arbitrary judgment exercised both in new projects and in the operation of boiler equipment, which did not always lead to satisfactory results.

He felt that the excellence of Mr. Shoudy's paper did not lie in its timeliness, since the subject had been discussed variously and at length elsewhere, but in the doctrine of moderation it bespoke, reflecting not the man alone but the very nature of the conditions which should characterize the subject. It was remarkable, he said, how lightly, very often under inexcusable circumstances, the functions of a boiler were considered, existing knowledge notwithstanding. Considering the matter of boiler capacity, he said that the general impression was that the capacity of a boiler bore a direct ratio to the available heating surface, while in reality the capacity of any boiler was no greater than the amount of fuel properly burned under it. In this connection he emphasized the word "properly," because, he explained, burning fuel completely regardless of the best combustion rate and under prescribed CO_2 conditions in the resulting gases did not by any means indicate that the fuel was "properly burned." He felt that there was no merit in wild feats in the course of regular practice, and that such terms as high ratings, high combustion rates, high CO_2, and high drafts, which drained the last drop of endurance of materials and of human effort, as well as peace of mind, were nothing short of wild feats which failed to pay dividends except in an emergency, and even in an emergency it was not a new doctrine to preach that moderation and prudence were dominating factors.

The functions of the stoker, furnace, and boiler were so intimately related with the necessary air and gas flow, he pointed out, that to complete the picture the draft equipment, whether a chimney or a combination of chimney and blowers, must be included. He felt that, with all our experience, somehow the value of draft regulation and gas flow with relation to the nature of fuels and boiler loading was not appreciated. High stacks tied to several boilers were often installed without regard to the nature of the load, except that they were required to take care of the maximum requirements. For very constant loading of a given number of boilers, such arrangement might be justifiable, he said, but constant loading seldom developed; more often the range of load was wide and fluctuating, in which case individual stacks with self-contained settings were by far to be preferred. High stacks operating at fractional loads, especially when operating a portion of the boilers for which they were intended at light loads, invariably resulted in uncontrollable high initial drafts at the furnace which induced localizing high combustion rates; in consequence, high velocities and in turn possible damage to the boiler, to say nothing of the very unsatisfactory performance, resulted.

The doctrine of high CO_2, he felt, had swept from sight all effort at common sense, the index of excellence of a boiler setting, in many cases, being judged by the ratio of kinship it bore to a producer of carbon dioxide; so long as the CO_2 was high, all was well, or

[2] Springfield Boiler Co., Springfield, Ohio.

ought to be. High CO_2, he explained, meant combustion with limited air, and the expectation, not unfounded on theoretical considerations, was that such a condition, susceptible of greater heat densities, would result in greater economies. Unfortunately, combustion with a limited amount of air did not prove to be uniform over the entire fuel bed, and in consequence neither the quality nor the flow of the gases was uniform, with the result that losses were incurred which could not be justified by theoretical considerations. Explaining further, he said that combustion with limited air meant high-temperature fires; high-temperature fires facilitated high combustion rates and accompanied undue wear and tear to the furnace. High combustion rates meant the possible use of small stokers, regardless of the nature of the fuel, which constituted the basis of the wrong. Stokers were sold and bought on the basis of their ability to burn completely large amounts of coal per retort, heedless of the consequences as to furnace upkeep and the functions of the boiler above them. Mr. Jacobi further pointed out that no special procedure was required in burning fuels completely at almost any rate within a given space, and with as little excess air as possible, but with relation to securing the best overall dollar economy of a boiler installation, with relation to producing steam at the least cost, there was a range of useful rates of combustion that could not be exceeded without detriment of some form. Unless particular provisions were made, the conditions of the load permitted it, and abundant skilled talent was in command, he recommended that high combustion rates under boilers be discouraged, or better still, suppressed. It was desirable, he said, that the CO_2 doctrine, if it must be accepted, be paralleled by a greater effort in learning to make and maintain useful fires. High CO_2 content in the gases of combustion might indeed be an index of ideal combustion of the fuel burned in the process of their formation, but by no means could it be considered an index of complete combustion of all the fuel fed into a furnace. High percentage of CO_2 might indicate waste, as revealed by the ash when operating boilers at high ratings and when the stokers were forced to their utmost. He stated that with moderate rates of combustion the following advantages would result: easier control of the fire; more thorough and uniform burning of all the fuel supplied; in consequence more uniform flow of the gases through the boiler passes, lower gas velocities and corresponding lower draft losses; more thorough distribution of the gases over the available boiler heating surface, in consequence more efficient transfer of heat and in turn more steam produced, therefore considerably lower exit-gas temperatures and in the end, less waste. Briefly, he explained, there was no comparison between the effects of high and moderate rates of combustion, and the moderate rates should be advocated.

Reference was made to Mr. Shoudy's suggestions as to the quantity in pounds of coal per square foot of grate area which should be considered as moderate combustion rates for various kinds of coal over the two leading types of stokers made, and emphasis placed on the fact that a pound of coal is not a pound of fuel, and, in order to be more nearly consistent with the facts, perhaps it were better that the permissible rates of combustion should be stated in terms of calorific density or in B.t.u.'s liberated per unit area of effective stoker surface. It was pointed out that a ruling on this point could easily be made to cover powdered coal and oil- and gas-fired boilers, since most of the difficulties with boilers fired with these forms of fuel were, in a large measure, due to concentrated or too rapid combustion, the results of which were comparable with high rates of combustion over stokers.

Still another reason given by Mr. Jacobi for instituting low rates of combustion within a furnace was the size and proportions of the furnace itself. It was his contention that, since the temperatures, the draft, and the gas velocities obtained with moderate rates of combustion were not so great, the size of the furnace might be made smaller and better proportioned than existing tendencies indicated.

Howard E. Bacon,[3] also in writing, pointed out the fact that just as in any composite problem the component parts were properly correlated, so in the seelction of steam-generating equipment the fuel-burning apparatus must be properly correlated to the other equipment involved.

The boiler should not be selected prior to the fuel-burning equipment, nor the fuel-burning equipment prior to the boiler. They should be selected jointly, together with the other apparatus involved by the plant heat cycle. As pointed out in the paper, the character of the plant load and steam output required would largely govern the choice of the size of the units, he said, whereas the burning characteristics of the intended fuel would determine the selection of fuel-burning equipment. The problem then resolved itself into one of harmonizing or correlating these two pieces of equipment together with such heat-reclaiming apparatus as might be used in such a manner as to secure the most economical results.

Mr. Bacon referred to the significant gain to be obtained in the use of higher-tube boilers, as pointed out in the paper, particularly when compared on the basis of equal steam output. It should be noted, however, he added, that this held true only when considering the boiler independently of the other apparatus. If heat-reclaiming apparatus were used, it might alter the plant heat cycle to such an extent that high flue-gas temperatures would be the most economical in the end, in which case the use of lower-tube boilers would be the correct choice. It was difficult, he said, to analyze only one phase of the cycle without regard to the other portions of it.

Mr. Bacon gave what he termed three basic or fundamental functions required of fuel-burning apparatus used for steam generation, as follows:

1 Induction of the fuel into the furnace
2 Efficient combustion of the fuel
3 Removal of extraneous or inert substances from the furnaces.

These three functions were accomplished in the modern stoker, he said, but there was too little appreciation of the degree to which the efficient combustion of the fuel was effected by the manner in which the stoker was fitted to the boiler. It was aptly pointed out in the paper that the per cent of combustible in the refuse and the per cent of carbon dioxide in the products of combustion constituted a measure of how well the stoker accomplished its second fundamental function, he explained, but too frequently a fault in application imposed a compromise from results that otherwise could be obtained if the application were correct.

Referring to the author's statement that the use of longer stokers was responsible for pushing the bridgewall back until it became the rear wall of the boiler setting, he said that this was due rather to the need for exposing greater surface to radiant heat, indicated by better stoker application.

Contrary to general belief, Mr. Bacon added, it was possible to set a boiler too high. Furnace volume was not the correct angle from which to determine the setting height; this should be determined from a study of the burning characteristics of the fuel, with particular reference to the flame length. Calling attention to the fact that radiant heat formed a large proportion of the boiler-heat absorption and that its rate varied as the square of the distance between the surface and the source, he showed that the boiler should be placed as close to the stoker as was consistent with the maximum flame length of the fuel used. The failure of high boiler settings was primarily due to excessive temperatures arising from interwall radiation before reaching the tube surfaces, he explained.

Mr. Bacon further pointed out that the angle of reflection of radiant-heat rays impinging on vertical furnace walls was so great that the reflective ray usually hit the opposite wall instead of the boiler heating surface. Slanting furnace walls had a tendency to decrease the angle, so that the heat rays were reflected into the tube surface, which explained the effectiveness of an inclined bridgewall in lowering furnace temperatures below the critical point for excessive slag or clinker formation.

Continuing, he pointed out the fact that although problems such as outlined above brought out pointedly the fact that furnace design or stoker application might affect stoker performance to a significant degree, yet no means of expressing efficiency of the furnace had been developed. All that could be done was to express it as a combination of stoker and furnace.

It was further argued that too little study had been made of the ash or clinker problem encountered in the operation of boilers from the chemical viewpoint. The older operators were accustomed to warn against the use of high-sulphur coal, but later investigation had shown that it was not the sulphur but the iron present, usually as pyrites, that was the disturbing factor. A study of the chemical

[3] Special Representative, Stoker Dept., Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. Jun. A.S.M.E.

characteristics of the components of the ash was very illuminating, he said, since it indicated that if the iron in the ferrous or bivalent state could be converted to iron in the ferric or trivalent state, slag formation would be minimized. This was due, he explained, to the fusing temperature of ferrous oxide being 2586 deg. fahr., or even lower, in the presence of other fluxing substances, while ferric oxide fused at 2840 deg. fahr. and was not affected by the presence of other substances. The conversion of the former to the latter was accomplished by the addition of heat and oxygen. If, in all the particles of ash that were carried up to the tubes by the velocity of the flue gas, the ferrous element should be converted to the ferric state, little adhesion to the tubes would occur. With the realization that a comparatively few degrees' change in temperature might place the clinker-forming material in a fusible state, the importance of furnace design was again emphasized.

Calling attention to the fact that a time element was involved in the completion of any chemical reaction, the writer showed that when preheated air was used for the combustion of fuel, this time element was decreased; or, conversely stated, the reaction was carried closer to completion. On this account, he said, one would expect to find all substances more completely oxidized. So far as the refuse was concerned, the ferrous iron was more nearly converted to ferric iron; consequently less trouble from clinker or slag formation would be encountered. This also explained the improved fuel-bed conditions which were obtained when operating with preheated air.

The above knowledge had made it possible to so apply underfeed stokers that when burning the middle-western coals having low fusing ash, performance comparable to that of eastern coals could be obtained. Underfeed stokers of both the dump-grate type and clinker-grind type were in successful operation using middle-western fuel having ash-fusion points as low as 1900 deg. fahr.

The elimination of operating difficulties encountered during "high rating" runs, Mr. Bacon explained, lay in securing a complete knowledge of the underlying causes and changing the application of the stoker in such a manner as to eliminate the cause of the trouble.

It was unusual to find a unit out of service due solely to stoker trouble, he said, it generally being a combination of difficulties in which the stoker played a minor part but might receive an undue amount of censure.

In concluding his discussion, Mr. Bacon suggested that the relation of the stoker to the boiler be considered from the broader angle of determining their relation to the other apparatus involved by the plant heat cycle, before any definite selection was made.

Discussing the author's statements regarding western coals, J. S. Bennett, 3rd,[4] offered written comment differing with the opinions expressed. Low-grade western coals, he said, had been burned on dump-type underfeed stokers for many years with great success. The substitution of a more modern underfeed dump stoker for older ones of the same type had shown a marked improvement in the operating results.

Kansas coal with the following analysis was being burned with great success at the Neosho Plant of the Kansas Gas and Electric Company.

Moisture	11.2 per cent
Ash	15.0 per cent
Volatile matter	28.3 per cent
Fixed carbon	45.5 per cent
Sulphur	4.24 per cent
B.t.u. per lb.	10,976

The results obtained at this plant were covered quite fully in an article which appeared in the November 15, 1925, issue of *Power Plant Engineering*, where the monthly boiler efficiency was reported as $78\frac{1}{2}$ per cent with a Stirling boiler operating at approximately 170 per cent of boiler rating. An underfeed stoker of the steam-dump type was used. The higher operating efficiencies of rotary ash-discharge underfeed stokers due to the greater recovery of carbon in the refuse, together with the stabilizing effect of the rotary ash-discharge type of stoker on general operation, were mentioned, as was also the fact that very remarkable results had been obtained with a rotary ash-discharge underfeed stoker in a western plant, where boiler ratings of from 350 to 400 per cent of rating had been maintained for prolonged periods of from 10 to 60 hours continuously, burning Iowa and Illinois coal with the following analyses:

Illinois Coal

Moisture	6.71 per cent
Volatile matter	36.41 per cent
Fixed carbon	38.52 per cent
Ash	18.36 per cent
Sulphur	4.6 per cent
B.t.u. per lb. as fired	10,576
Fusing temperature of ash	1990 deg. fahr.

Iowa Coal

Moisture	13.4 per cent
Volatile matter	33.1 per cent
Fixed carbon	32.8 per cent
Ash	20.7 per cent
Sulphur	6.85 per cent
B.t.u. as fired	9200
Fusing temperature of ash	1920 deg. fahr.

Recent tests, he said, had shown the boiler and economizer efficiency to be from 86 to 88 per cent within the normal range of operation.

In closing, Mr. Bennett said he had found that, if anything, higher fuel-burning rates could be maintained with the low-grade western coals than could be used successfully with the better grades of eastern coals. Of course, to permit a high fuel-burning rate, he pointed out, it was necessary to provide adequate side- and rear-wall protection to prevent clinker adhesion, and the stoker should be so designed that the fuel in any portion of the fuel bed could be controlled independently of any other part.

Discussing the paper orally, David Moffat Myers[5] referred to the absence throughout the discussion of any mention of cost in each of the different combinations, which was the deciding factor. The engineer, he said, must not only work out his heat cycle but he must also convert his thermal efficiencies into what might be termed commercial efficiencies, so that the final set of curves would show which combination of apparatus would produce the greatest results per dollar.

Referring to attempts to reach higher boiler efficiencies, N. E. Funk[6] urged that it be borne in mind that there were always dangers in trying to stretch material too far, but if the limit were approached with intelligence and somewhat slowly, there was probably no limit within reason that could not be reached. He believed that the limit would be a financial one.

He felt that in comparing the efficiencies of five 14-high boilers with three 24-high boilers, the differences might have been much greater if the economic efficiency rather than the mechanical efficiency had been considered; that was, five individual units, although smaller, would cost more than the three larger individual units.

Regarding the design of furnace walls, he said that boiler design had grown up very much like the pottery industry; we had been doing things the way our grandfathers did in the beginning, and then by piling something on at one point and then at another finally got in one part of the country a result different from that obtained in another. He maintained that we had made soaking pits of our furnaces, and had made them out of our refractories, depending on the radiant heat striking a refractory and reflecting to the cooling surface of the boiler.

He felt that in the future furnaces would be considered more from the point of how much heat could be absorbed in the total furnace than from how much the exterior of the boiler could be insulated from the heat in the fire. He also felt that the solid refractory wall was practically a thing of the past.

C. G. Spencer,[7] referring to Mr. Shoudy's six general headings covering troubles usually encountered in stoker operation at high ratings, suggested two additional headings, Draft Limitation, and Furnace Volume and Design. Under the former, he said, there was not only the draft at the exit of the boiler or the boiler damper to be

[4] Assistant Engineer, American Engineering Co., Philadelphia, Pa. Mem. A.S.M.E.

[5] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[6] Operating Engineer, Philadelphia Electric Co., Philadelphia, Pa. Mem. A.S.M.E.

[7] Engineer, McClellan & Junkersfeld, Inc., New York, N. Y. Mem. A.S.M.E.

considered, but the draft throughout the boiler due to the baffling.

Regarding the second, furnace volume, he pointed out that without proper volume or proper height of furnace, so that the combustion would be complete before the gases entered the tubes, the selection of stoker and boiler might not be successful.

Regarding the early use of stokers, Albert A. Cary[8] stated that in the early nineties they were used more to save labor than to increase the capacity of boilers. The necessity for an increased capacity brought the underfeed stoker.

During the World War, when it was necessary to get more steam out of existing plants, due to the shortage of boilers resulting from the boiler concerns working on war work, it was a question of pushing the furnace so as to increase the capacity of the boilers from 100 to 200 per cent. Since the war, he said, this increased furnace capacity had been rushed, resulting in the appearance of oil-burning systems and pulverized-coal equipment and their very general use. During this time the overfeed stoker had been neglected, although he saw in it great possibilities.

The great trouble, Mr. Cary explained, lay in the fact that an overfeed, inclined-grate stoker could not be forced much beyond the capacity of the boiler to which it was attached, simply because the use of a forced blast under the grates resulted in their burning out almost as rapidly as they could be replaced, and clinker trouble interfered with the operation of the plant, sometimes causing a complete shutdown.

He then mentioned remedial efforts at the plant of the Edison Electric Company of Boston, in which steam-jet blowers were placed under the Murphy stokers, resulting in a slight increase in capacity. Since then, he added, means had been found for applying a forced blast to this type of stoker. The coal was fed over the top of the fuel bed, and as the gas was distilled off the fixed carbon dropped, until when it finally reached the grate it encountered a perforated cooling member, resembling the top of a pepper box. Clinker troubles were practically eliminated, and as high as 60 lb. of coal per square foot of grate was burned. That meant nothing, he added, unless the kind of coal burned was considered.

With the western coals, he explained, where, say, 50 per cent of the fuel content was gas, that gas, of course, was burned in a combustion chamber above, whereas with the eastern bituminous coals, with the volatile running from 18 to 22 per cent and the ash very low, a great deal of fixed carbon had to be burned directly upon the grates. There was very little trouble from ash clinkers adhering to the side walls, due to the motion of the grate shearing the ash away from those walls and keeping them clear so that the ash would not fuse them.

Regarding the burning of anthracite coal, he agreed with Mr. Shoudy that best results were obtained on the chain-grate stoker.

The speaker then related his experiences with anthracite coal when using a certain brush and burnisher apparatus. The coal was simply brushed upon the surface of the grate, the speed of the fan being regulated to distribute it over the front or the rear part of the grate as needed. There was a double brush, and one side or the other could be built up by distributing the coal over the top surface of the fire bed. With a shaking-grate attachment underneath, he succeeded in getting the best results he had ever obtained from anthracite coal.

Hosea Webster[9] felt that it would be a mistake to be guided by the suggestion that boiler rating meant nothing, for the reason that there was an extremely intimate relation between boiler rating and flue-gas temperature.

R. S. Baynton[10] described a power plant which he had recently designed and constructed for an industrial mill to operate at 425 lb. pressure, using highly preheated air. Briefly, three 500-hp. boilers 15 high and 15 wide were provided. They were operated at an average of about 200 per cent of rating. The air temperature varied from 400 to about 450 deg.

Regarding operating results, over three months the stack temperatures in the preheater varied from 250 to 300 deg. The CO_2 was about $13^1/_2$ per cent, for a very high grade of coal of about 14,500 B.t.u., with about 78 per cent fixed carbon, 17 per cent volatile, and about 5 per cent ash.

Compared with old furnaces using the same coal, the new furnaces with preheated air showed practically no slagging and no apparent depreciation of refractories.

Regarding stoker parts, there was a certain small amount of trouble, but it was not disastrous and was being overcome.

The speaker emphasized the fact that in raising the height of the boiler from, say, 14 to 25 tubes, one must remember that the area of the tubes exposed to the radiant heat from the furnace was reduced. He regarded it as most important that as much of the boiler heating surface as possible be exposed to the direct radiant heat from the fire. He explained that in adding banks of tubes to the top of the boiler one endeavored to take off heat units which, especially with high pressures, would be taken off with a minimum of temperature difference between the gases and the water. Of course, he said, if one put in air preheaters instead of dealing with the material at 460 deg., the temperature of the steam and the water in the boilers, one would get heated material at around 80 to 100 deg., which seemed a very obvious way of getting out all of the heat. He considered a temperature of 280 deg. for the stack gases a fairly good figure.

Using preheated air, he estimated that the furnace height could be dropped three to four feet.

Comparisons based on fuel costs were unsatisfactory, he felt, and he recommended consideration of efficiencies, for then one had a common basis of comparison and argument.

[8] Consulting Mechanical Engineer, New York, N. Y. Mem. A.S.M.E.

[9] Sales Manager, Babcock & Wilcox Co., New York, N. Y. Mem. A.S.M.E.

[10] The Chesapeake Corporation, West Point, Va.

Elimination Work in the Selection of Personnel[1]

WASTE elimination in the selection of personnel demands, first of all, job analysis, personality analysis, and job betterment in order that the best opportunities may be made available for workers and that as exact information as possible may be on hand in regard to the type of work which the worker is expected to do.

In the second place, the problem of getting desirable applicants to apply may be solved in large measure through the "three-position plan of promotion," which provides for satisfied workers bringing satisfied workers to the organization.

The next problem, that of selection, includes adequate physical examinations, psychological tests, and, if possible, psychiatric tests. Psychological testing is today becoming more sound as to theory and more practical as to practice. Lower limits are being established, speed and accuracy are receiving definite consideration, behavior is being recorded, and likes and dislikes noted.

Teaching is receiving increasing consideration, the technique of advanced educational practice is being adopted. Care must be taken that the teacher knows the industry where the teaching is being done, keeps abreast of advances in the educational field, and is able to "sell" his instruction.

Turnover is now being recognized as serious only when it causes individual failure on the part of the worker or management to make good. Much turnover, as a matter of fact, indicates industrial progress. All turnover figures must be carefully studied, causes traced, and appropriate procedure outlined.

The most serious waste today is in the field of promotion. This may be saved by selecting applicants apparently below the job who can be trained to do the work and get satisfaction in it. Periodical personality analyses will show possibilities for promotion and some plan like the "three-position"—which means that every man in the organization holds three jobs, one in the work he is doing, one as teacher to the worker in the job he has left, and one as student in the next job he is to fill—will provide opportunities and outline profitable lines of advancement.

We have to report advance in all lines of eliminating waste in handling the human element, especially in selection, placement, and teaching, but there is yet special need for progress in the promotional field.

[1] Abstract of talk given by Lillian M. Gilbreth, before the A.S.M.E. and Taylor Society, New York, October 26, 1926.

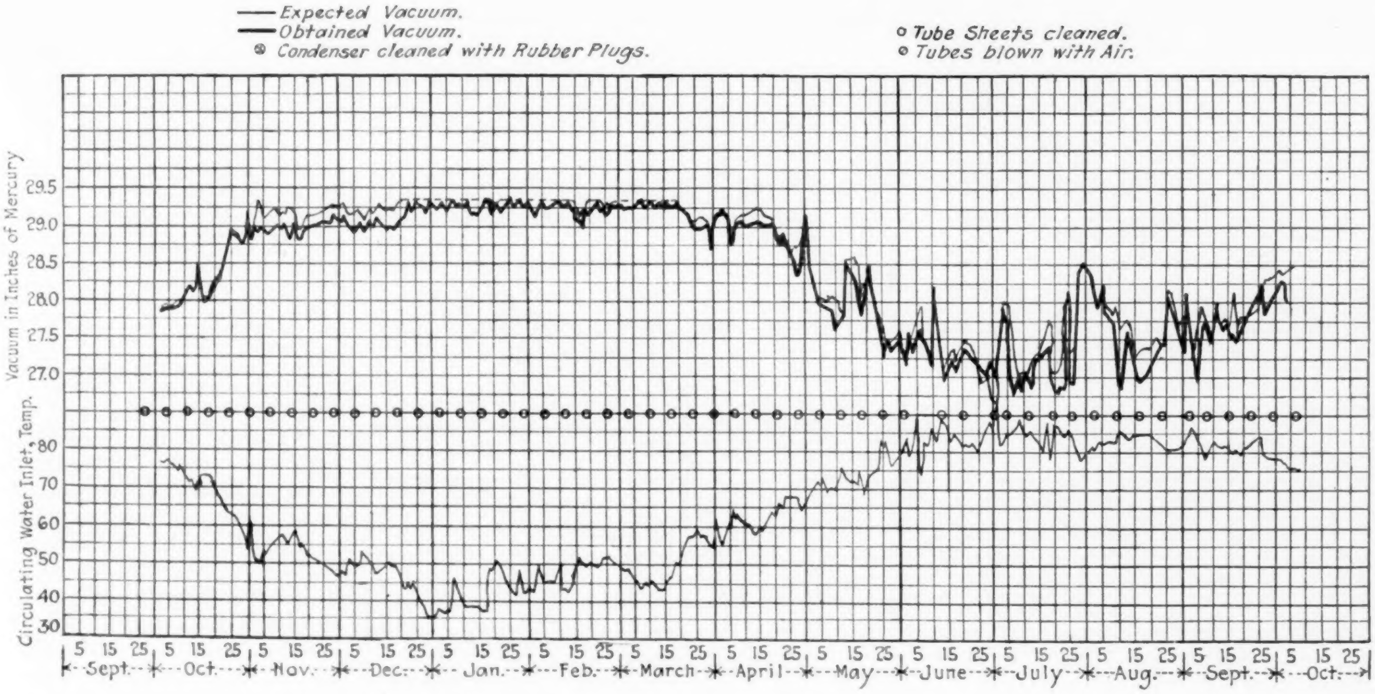


FIG. 1 CONTINUOUS GRAPHIC RECORD OF THE PERFORMANCE OF INGERSOLL-RAND 9000-SQ.-FT. CONDENSER SERVING 12,500-KW. TURBINE AT THE BROAD RIVER POWER COMPANY, PARR, S. C., DURING THE LATTER PART OF 1925 AND NINE MONTHS OF 1926

(This was plotted by the Operating Department of the W. S. Barstow Management Association, Inc., and shows a comparison of obtained vacuum with expected vacuum. The large variations in vacuum during the summer of 1926 are due principally to wide variations in load.)

Operating Performance of Some Modern Surface Condensers

BY PAUL BANCEL,[1] NEW YORK, N. Y.

By means of operation records, this paper shows (1) that a modern condenser requires about half the cooling surface of the conventional type; (2) that there is no essential difference between operating and test performance; (3) that the results obtained are based on fundamental improvements in design which produce high efficiency in the utilization of the surface with small expenditure of power; and (4) that the change from a two-pass to a single-pass hydraulic circuit is the result of improved efficiency and not the cause.

WHEN the Ingersoll-Rand condenser was introduced, it was claimed that the usual cooling surface could be greatly reduced; that is, 10,000 sq. ft. would do the work of 20,000 sq. ft. and 25,000 sq. ft. the work of 50,000 sq. ft. with equal auxiliary power in both cases. So radical a claim was of course immediately challenged. With one-half the surface, the heat-transfer coefficient would naturally be doubled, and criticism simmered down largely to the foolhardiness, or worse, of using so high a coefficient in the face of all the experience and practice of past years. It was argued that condensers of conventional design were not the crude machines of prewar days, but were, in fact, already highly efficient, as demonstrated by tests showing coefficients of 500, 600, and 700 as against those of 300 to 500 used when calculating the cooling surface. Therefore, using test results as a basis of size was sacrificing a very essential and large margin of safety.

One test of a 50,000-sq.-ft. condenser at the Waterside Station of the New York Edison Company was frequently cited a few years ago (see 1924 N.E.L.A. Condenser Report, p. 43). A coefficient of 600 was shown under conditions of cold water and high vacuum where considerably lower heat transfer was expected than in summer, and 300 to 400 would have been considered excellent. Since that time the author's company has installed a unit in the same plant, and the same work is being performed with 60 per cent of the surface, with the same or less water, and with considerably less friction which is to be credited to the performance. While the previous unit had shown a coefficient of 600, the Ingersoll-Rand unit has never shown a 1000 or 1200 coefficient but, nevertheless, produces the same operating results year in and year out.

It is apparent, therefore, that many tests and fragmentary readings on condensers are of little or no value. As with a boiler plant, the real test of condenser performance is that obtained in continuous operation. Results of this kind are presented in the following pages and similar operating results should be used for comparison.

Comparisons should also be made with the latest single-pass condensers of other types. Recently it has been argued that the performance of any type of condenser can be improved by making it single-pass instead of two-pass. Many such condensers have been put into service within the last year or two which are of at least as recent design as those covered in this paper, and a comparison of complete operating results would be of great interest.

Fig. 1 shows a year's performance on an Ingersoll-Rand condenser of 9000 sq. ft. surface carrying loads as high as 16,000 kw. and condensing 168,000 lb. of steam per hour. This is the day-to-day check of the operating department.[2] Table 1 gives details of this condenser and also of other units referred to later. Fig. 2 shows fifty days' performance in detail. Fig. 3 shows a straight-line chart of the performance of this condenser with one set of points covering 1925 and the other 1926.

Fig. 4 shows typical daily reports used as the basis for Figs. 1, 2, and 3. Calculations from the figures will show heat-transfer

[1] Ingersoll-Rand Company. Mem. A.S.M.E.

Contributed by the Power Division and presented at the Annual Meeting, New York, December 6 to 9, 1926, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

[2] Figs. 1, 4, and 5 are reproduced through the kindness of J. A. Powell, Mechanical Engineer, and E. M. Gilbert, Vice-President and Chief Engineer, of the W. S. Barstow Management Association, Inc.

TABLE 1 DATA ON VARIOUS CONDENSERS

	Location	Date of installation	Surface Sq. ft.	No. passes	Tubes No.	Tubes Size, in. O.D.	Tubes Gage	Tubes Length ft.	Circulation Water quantity, gal. per min.	Circulation Velocity ft. per sec.	Circulation Friction, ft.	Nature of circulating water	Steam jets Operating steam, lb. per hr.
Broad River Power Co.	Parr, S. C.	Oct., 1925	9000	Single	2300	3/4	17	20	22,000	9.6	14.5	Broad River, fresh, muddy. Summer temperature 80° to 90°	1000
Broad River Power Co.	Parr, S. C.	Aug., 1926	25,000	Single	5800	3/4	17	22	45,000	7.8	12	Broad River, fresh, muddy. Summer temperature 80° to 90°	1000
N. Y. Edison Co. Waterside Station	Waterside No. 1, New York City	Oct., 1924	30,000	Single	6000	7/8	18	22	70,000 (rated) (55,000 to 60,000,) (operation in 1925)	7.9 6.5 (average)	10 7	Salt water, sewage contamination, New York, East River, summer temperature 70° to 75°	1800
City of Pasadena	Pasadena, California	May, 1924	14,100	Single	3582	3/4	18	20	22,000	5.9	7	Cooling tower, algae and slime form in tower and tubes. Summer temperature 90° to 100° maximum, 107°	1500

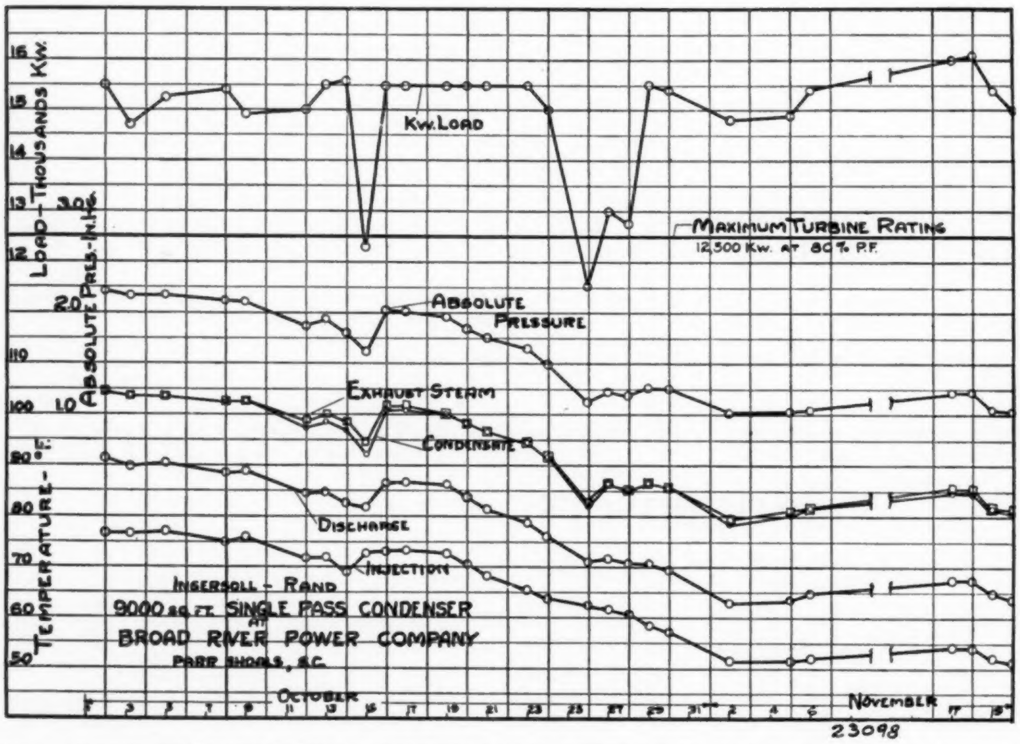


Fig. 2 Continuous Graphic Record of the Performance, During the First One and One-Half Months, of the 9000-Sq-Ft. Condenser at the Broad River Power Company, Parr, S. C., as Shown in Fig. 1

at Waterside Station, New York Edison Company. The tests were based on 70,000 gal. per min., the rated water, and are corrected to average operating water quantity by the usual method—lines A' and B'. Due to local conditions the pumps (turbine-driven) were operated at reduced speed, and the water quantity averaged 55,000–60,000 gal. per min. as shown by the temperature rise.

These operating readings were taken once each day. The daily performance is consistent with the test performance, but what is of more significance, the results after a month and a half were practically the same as on the day of the test.

Fig. 9 shows operating and test readings taken from two months to two and one-half years after installation of a 14,100 sq-ft. unit at the City of Pasadena municipal plant. A significant feature of these results is the fact that excellent performance and high heat transfer are obtained at low velocities (see Table 1). The test results were obtained after "shooting" the tubes with corks to remove the slime.

coefficients over 800, as would be expected. Fig. 3 shows that the performance of the summer of 1925 was repeated in 1926. The loads approach 20 lb. per sq. ft., which is believed to be a record for a land condenser with circulating water at 80 to 90 deg. fahr. in summer. The straight-line chart is used in Fig. 3 and elsewhere because it is a convenient way of eliminating erratic values and has the advantage that the line drawn is made with a straight edge. Appendix No. 1 explains the straight-line law.

Fig. 5 shows the performance of a 25,000-sq.-ft. unit in the same plant serving a 38,000-kw. (maximum rating) Westinghouse turbine. This chart is also furnished by the W. S. Barstow Management Association.

Fig. 6 shows the straight-line law based on a number of these readings as given. At 240,000 lb. load the difference between exhaust steam and water temperature is 17 deg.; at 300,000 lb. load it is 21.2 deg. or a vacuum of 28 in. with 80-deg. water. Comparison should be made with the monthly performance of 50,000-sq.-ft. units installed for similar service within recent years, including load, water quantity, condenser friction, and air-pump power or steam-jet quantity.

An interesting feature of this condenser is that it is hung entirely from the turbine, Fig. 7. There are no spring supports. A second feature is the small basement height—22 ft. from floor to floor.

Fig. 8 shows about 50 days' operation and test results of a 30,000-sq.-ft. condenser under a 35,000-kw. non-bleeding turbine

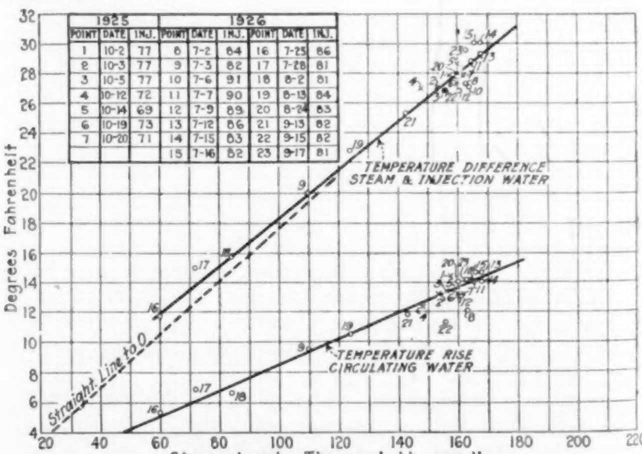


Fig. 3 Performance in Summers of 1925 and 1926 of the Ingersoll-Rand 9000-Sq-Ft. Condenser at the Broad River Power Company Plotted to the Straight-Line Law

(The chart shows the difference between steam temperature and injection temperature; also the temperature rise of the circulating water. The table gives the actual injection temperatures. It will be noted that there is no difference in the performance in 1926 as compared to 1925.)

Form No. 796—3-17-26—5000 THE W. S. BARSTOW MANAGEMENT ASSOCIATION, INC., OPERATING MANAGERS

OPERATING DEPARTMENT

RECORD OF SURFACE CONDENSER PERFORMANCE

Company Broad River Power Co. Unit No. ______

Location Connected to Parr, S.C. Turbine 12500 K.W.

Condenser Size 9000 Sq. Ft. Maker Ingersoll-Rand

Date	July-12-26	3:00 P.M.	M.	M	M.	M.
Load in K. W. on engine or turbine		15600				
Total steam flow, lbs. per hr.		168000				
Steam pressure at turbine (engine) throttle gauge lbs. per sq. in.		305				
Steam temperature at turbine (engine) throttle °F.		668				
Main Unit primary inlet pressure lbs. per sq. in.		300				
Main Unit secondary inlet pressure lbs. per sq. in.						
Barometer {Mercurial / ~~Aneroid~~} Located ____ feet {Above / Below} Condenser		29.81				
1 Vacuum at top of condenser by mercury column		26.80				
2 Temperature at top of condenser °F.		115.0				
3 Temperature condensate pump water °F.		114.25				
4 Vacuum at air connection at condenser by mercury column						
5 Temperature of air in air line at condenser						
6 Temp. injection water inlet °F.		85.75				
7 Temp. injection water end of first pass °F.	Top outlet	100				
8 Temp. injection water discharge °F.	Bottom outlet	100.75				
9 Vac. air pump injection inlet						
10 Circulating pump suction {inches vac. / ~~lbs. pres.~~}						
11 Condenser injection inlet {inches ~~vac.~~ / ~~lbs.~~ pres.}	Hg.	13.8				
12 Condenser discharge water pres. {inches vac. / lbs. pres.}	Hg.	2.3				
13 Condensate pump discharge pres.—lbs. per sq. in.						
14 Level of condensate water above centre line of condensate pump		22.5				
15 R. P. M. circulating pump						
16 R. P. M. condensate pump						
17 Inlet steam pressure for condenser pump drives						
18 Inlet steam pressure for air ejectors		109				
19 Number of primary ejectors in service		4				
20 Number of secondary ejectors in service		2				
21 Oxygen (mls. per liter) B-Feed. 140 at 204 Hard .0			°F		°F	E
22 Hardness of condensate (parts per 100,000 as $CaCO_3$)	.0					27.04
23 Oxygen. Cond. 196 at 112						0
24						27.03

Remarks: Added oil Turbine #1 Sunday July 11th 1926

Signature A. G. Moultrie

Form No. 796—3-17-26—5000 THE W. S. BARSTOW MANAGEMENT ASSOCIATION, INC., OPERATING MANAGERS

OPERATING DEPARTMENT

RECORD OF SURFACE CONDENSER PERFORMANCE

Company Broad River Power Co. Unit No. ______

Location Connected to Parr, S.C. Turbine 12500 K.W.

Condenser Size 9000 Sq. Ft. Maker Ingersoll-Rand

Date	July 15-26	4:30 P.M.	M.	M	M.	M.
Load in K. W. on engine or turbine		15600				
Total steam flow, lbs. per hr.		168000				
Steam pressure at turbine (engine) throttle gauge lbs. per sq. in.		305				
Steam temperature at turbine (engine) throttle °F.		682				
Main Unit primary inlet pressure lbs. per sq. in.		301				
Main Unit secondary inlet pressure lbs. per sq. in.						
Barometer {Mercurial / ~~Aneroid~~} Located ____ feet {Above / Below} Condenser		29.86				
1 Vacuum at top of condenser by mercury column		27.1				
2 Temperature at top of condenser °F.		113.0				
3 Temperature condensate pump water °F.		112.25				
4 Vacuum at air connection at condenser by mercury column						
5 Temperature of air in air line at condenser						
6 Temp. injection water inlet °F.		83				
7 Temp. injection water end of first pass °F.	Top Outlet	97.0				
8 Temp. injection water discharge °F.	Bottom "	97.0				
9 Vac. air pump injection inlet						
10 Circulating pump suction {inches vac. / ~~lbs. pres.~~}	Hg.	16.0				
11 Condenser injection inlet {inches ~~vac.~~ / ~~lbs.~~ pres.}	Hg.	2.0				
12 Condenser discharge water pres. {inches vac. / lbs. pres.}						
13 Condensate pump discharge pres.—lbs. per sq. in.		out of order				
14 Level of condensate water above centre line of condensate pump						
15 R. P. M. circulating pump						
16 R. P. M. condensate pump						
17 Inlet steam pressure for condenser pump drives						
18 Inlet steam pressure for air ejectors		109				
19 Number of primary ejectors in service		4				
20 Number of secondary ejectors in service		2				
21 Oxygen (mls. per liter)		196	112 °F	.168	203 °F	E
22 Hardness of condensate (parts per 100,000 as $CaCO_3$)						27.26
23						0
24						27.18

Remarks: Cleaned Condenser Sunday July 11th 1926

Signature A. G. Moultrie

FIG. 4 OPERATOR'S TYPICAL DAILY REPORTS OF CONDENSER PERFORMANCE, SHOWING PRINTED FORM USED AND TYPICAL READINGS
(These daily reports are used as a basis for charts such as Fig. 1 and Fig. 5, which are plotted continuously by the statistical division of the Operating Department.)

Condensate Temperature

Fig. 2 shows condensate temperatures at practically steam temperatures. The condenser shows a condensate temperature about 3 deg. under steam temperature. The two remaining condensers show very hot condensate, the 30,000-sq.-ft. unit being fitted with a reheating hotwell. Detailed figures need not be given since, with modern stations and extraction heating, condensate temperature has little or no effect on plant economy. This is now widely recognized.[3]

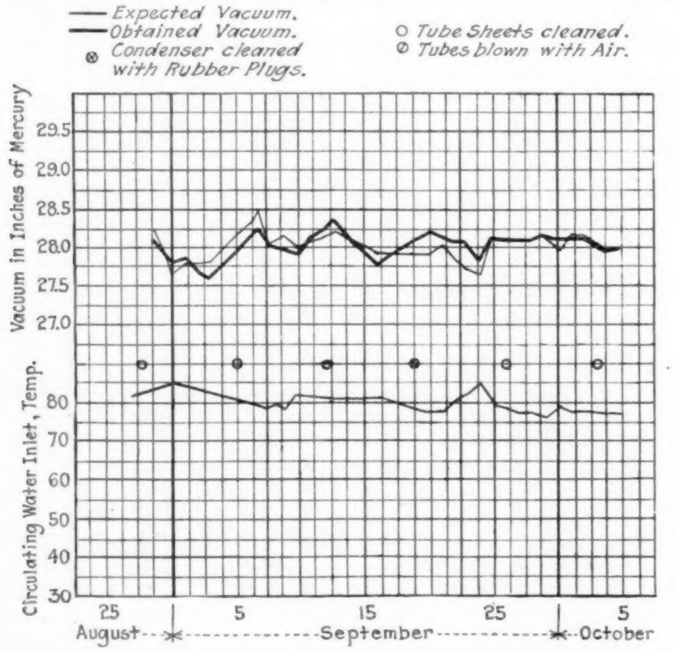


Fig. 5 Approximately 40 Days' Performance of the Ingersoll-Rand 25,000-Sq.-Ft. Condenser Serving the 38,000-Kw. (Maximum Rated) Turbine at the Broad River Power Company, Parr, S. C.

(This chart also was plotted by the Operating Department of the W. S. Barstow Management Association, Inc., similar to Fig. 1.)

Condenser Efficiency

It has been frequently argued that no marked difference in efficiency could exist between different condensers, and that the only merit in the Ingersoll-Rand design was the use of a single pass, smaller tubes, higher velocity, excessive water, and large power. Velocities, frictions, and water quantities are given in Table 1 and are checked by temperature rise in the various charts. It will be noted that the velocities are little higher than the range of 5 to 8 ft. per sec. employed in conventional condensers. The gain to be expected from velocity and tube size can readily be isolated, thus indicating what remaining gain must be the result of efficiency.

From Fig. 10, a two-pass condenser with 1-in. tubes and a single-pass condenser with $^3/_4$-in. tubes have the same friction at velocities of 6 and 8 ft. per sec., respectively. With these ratios of velocities and the same total water quantity, a brief calculation of number of tubes, areas for water flow, etc., shows that the single-pass unit with $^3/_4$-in. tubes would have about half the surface of the two-pass unit with 1-in. tubes. This is not strictly correct, but is sufficiently close to serve as an example without introducing unwieldy figures.

Due to the higher velocity, the $^3/_4$-in. tubes would have an advantage corresponding to $\sqrt{8/6}$ or 115 per cent in heat transfer. The further advantage of the $^3/_4$-in. diameter as against the 1-in. diameter would increase this to about 125 per cent.

If the single-pass condenser of half the surface is to do the same work, there must be about double the heat transfer per square foot. It follows, therefore, that as only 25 per cent gain can be expected from velocity and tube size, a large improvement must be obtained from internal efficiency. The efficiency must be increased to 200/125 or 160 per cent of what it was in the two-pass condenser. The principal gain must come from this source.

Condenser efficiency is the ratio of the overall heat transfer to that for some standard conditions of tube velocity, temperature, diameter, etc., or—

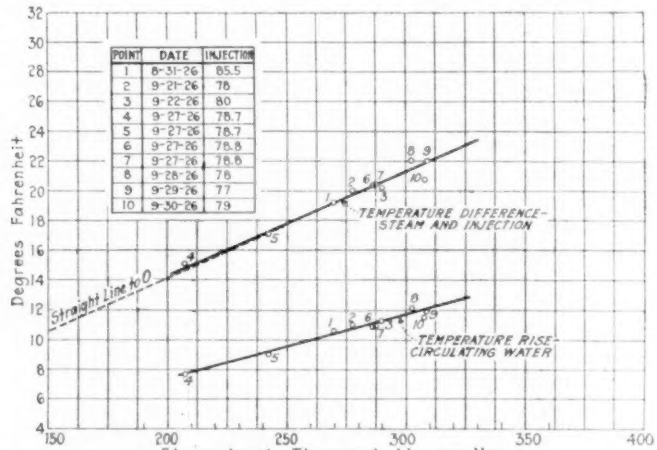


Fig. 6 Straight-Line Chart Showing Performance with Warm Water of the Ingersoll-Rand 25,000-Sq.-Ft. Condenser Serving the 38,000-Kw. (Maximum Rated) Turbine at the Broad River Power Company, Parr, S. C.

(The chart shows the difference in temperature between the exhaust steam and the injection water; also the rise in temperature of the circulating water. The small table shows the actual injection temperature.)

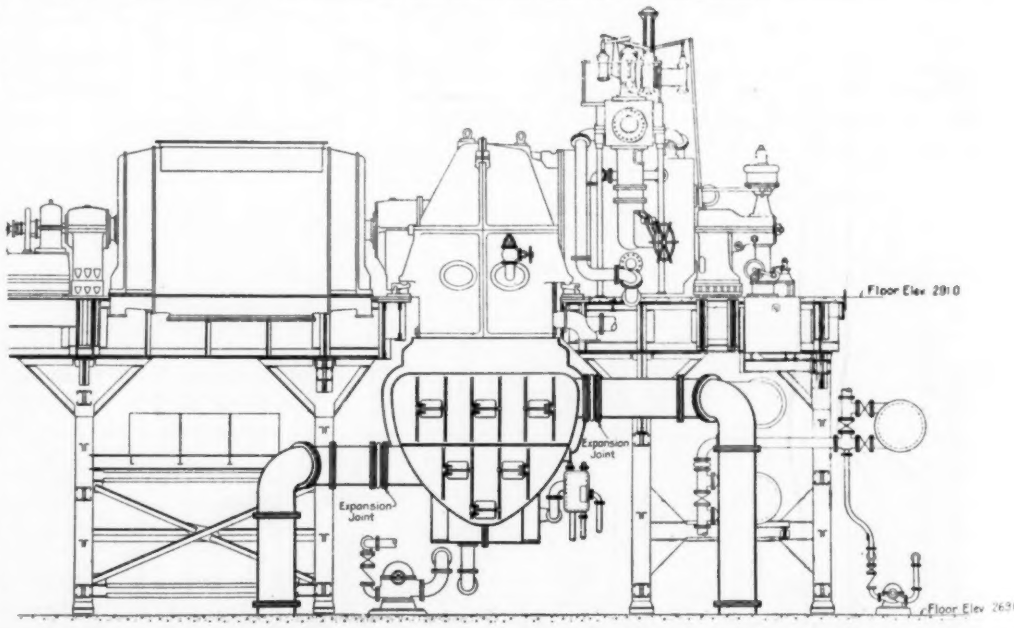


Fig. 7 General Arrangement of Turbine and 25,000-Sq.-Ft. Ingersoll-Rand Condenser, Unit No. 2, Broad River Power Company, Parr, S. C.

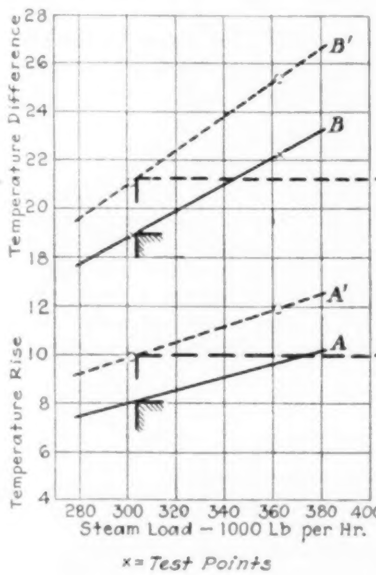
(The condenser is bolted direct to the turbine and hangs entirely from the turbine without any spring supports. The basement height, as shown by elevations, is 22 ft. The drawing shows the discharge end of the condenser.)

[3] Refer to January, 1926, N.E.L.A. Report, p. 1, par. 4. "With installations using stage bleeding, a moderate depression of hotwell temperature is of little consequence in the general heat balance, despite the frequent use of such differences as a basis of comparison of condenser results." It is important, however, that the condensate be low in oxygen, and this is obtained. In recent tests the condensate shows 0.05 cc. per liter.

Efficiency ratio =

$$\frac{\text{Overall heat transfer}}{\text{Single-tube heat transfer}}$$

The denominator is the heat transfer in a calorimeter, with a single tube taken from the condenser, tested at the same conditions of temperature, velocities, cleanliness, etc. The ratio is analogous to the Rankine-cycle efficiency ratio of a turbine. It is a measure



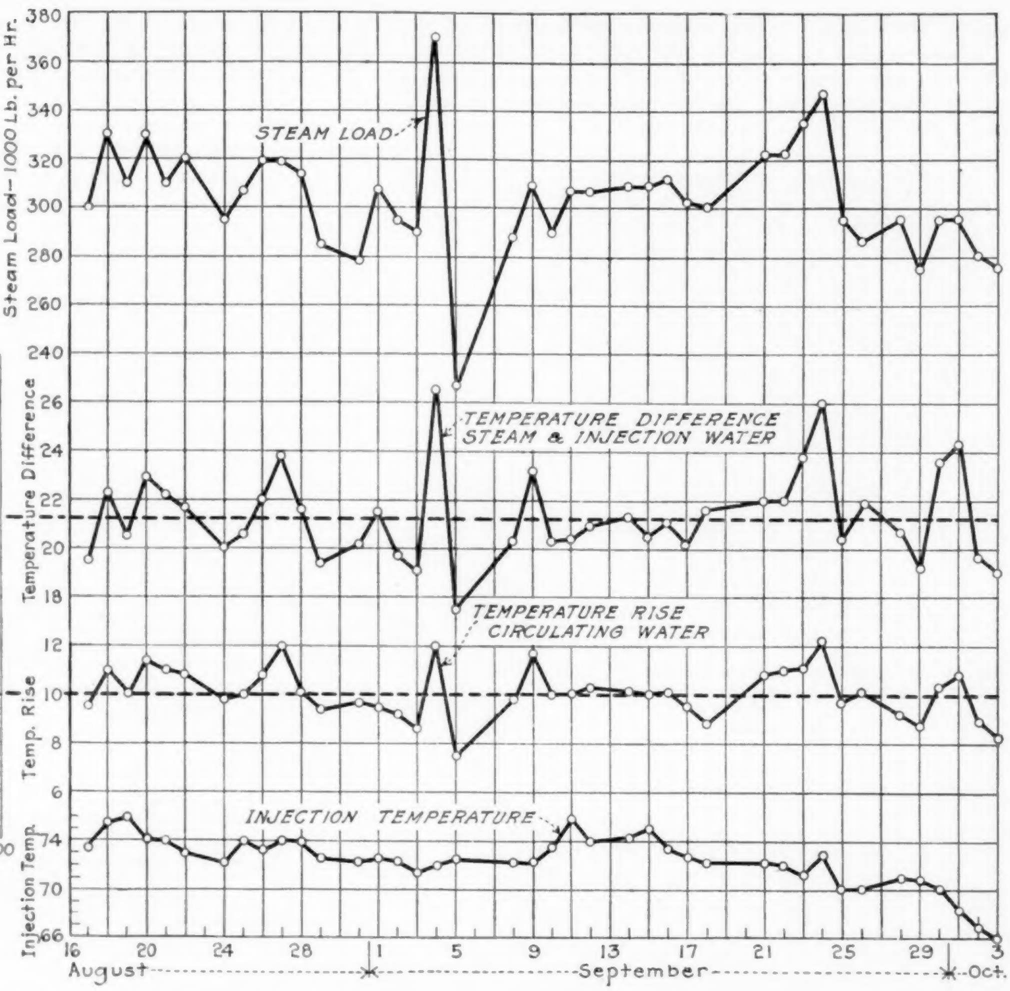
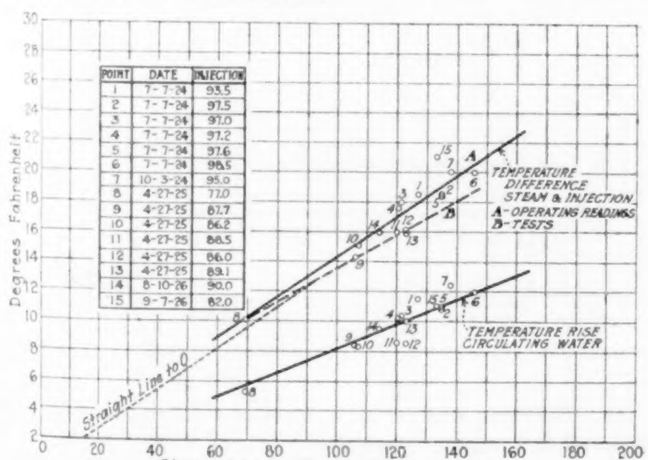


FIG. 8 TEST PERFORMANCE AND 50 DAYS' OPERATING PERFORMANCE OF AN INGERSOLL-RAND 30,000-SQ.-FT. CONDENSER AT THE NEW YORK EDISON COMPANY, WATERSIDE STATION, SERVING A 35,000-KW. NON-BLEEDING TURBINE

(The test points showing temperature difference against load are shown by *B* at the left, with rated water 70,000 gal. corresponding to temperature rise as shown by *A*. The condenser was operated with reduced water as shown by the graph of temperature rises. The test results, corrected for the reduced water, are shown by lines *A'* and *B'*. The dotted lines at the right of the chart show temperature rise and temperature difference expected from tests, and are to be compared with actual results obtained for 50-day period.)



POINT	DATE	INJECTION
1	7-7-24	93.5
2	7-7-24	97.5
3	7-7-24	97.0
4	7-7-24	97.2
5	7-7-24	97.6
6	7-7-24	98.5
7	10-3-24	95.0
8	4-27-25	77.0
9	4-27-25	87.7
10	4-27-25	86.2
11	4-27-25	88.5
12	4-27-25	86.0
13	4-27-25	89.1
14	8-10-26	90.0
15	9-7-26	82.0

FIG. 9 STRAIGHT-LINE PLOTTING OF PERFORMANCE AND TEST OF INGERSOLL-RAND 14,100-SQ.-FT. CONDENSER, PASADENA, CAL.

(Condenser operates in connection with cooling tower and very warm water as shown by the table.)

of what is accomplished with thousands of tubes as against one tube.

The efficiency ratio is a variable not only with design but with operating conditions. At zero load the vacuum cannot attain the theoretical value corresponding to water temperature on account of the air leakage. Hence the efficiency is zero and all efficiency

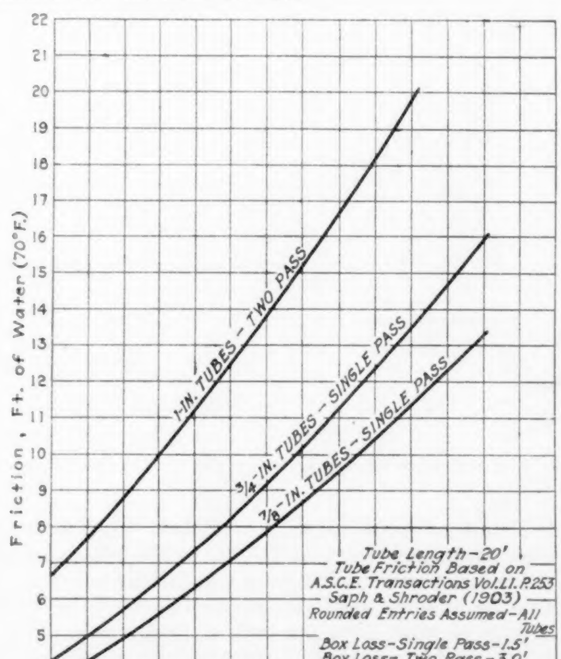


FIG. 10 COMPARISON OF THE FRICTION IN A 1-IN. TWO-PASS CONDENSER WITH THAT IN $^3/_4$-IN. AND $^7/_8$-IN. SINGLE-PASS CONDENSERS

(A 6-ft. velocity in a 1-in. two-pass condenser gives the same friction as an 8-ft. velocity in a $^3/_4$-in. single-pass condenser.)

curves rise from this point, attaining values depending on design.

Efficiency must be obtained with small air-pump power. Extra steam-jet quantities of 1000 to 2000 lb. are frequently used in test or even in operation, and to quote heat transfers as obtained under these conditions without mention of the steam quantity,

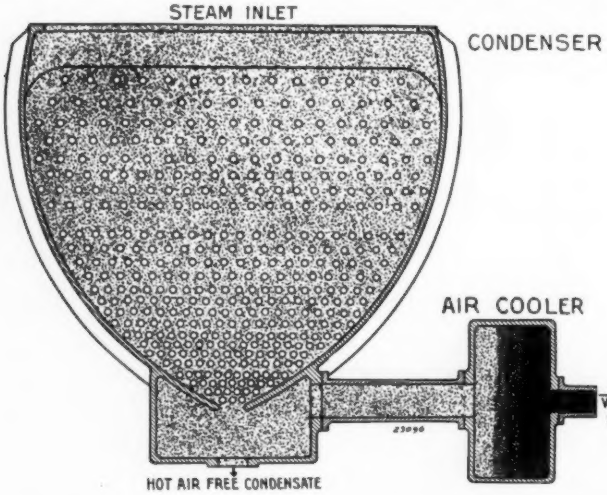


Fig. 11 Arrangement of Tubes, Shell Shape, Hotwell, Vapor Outlet, and Air Cooler in an Ingersoll-Rand Condenser

In the case of the 30,000-sq-ft. Waterside condenser, tests show that the air leakage can be artificially doubled (from about $6^1/_2$ to 13 ft.) without change in vacuum.

In the case of the 25,000-sq-ft. Broad River unit, a definite guarantee of steam quantity with definite air leakage was called for by the purchaser to correspond to the vacuum performance of the condenser. Recently similar requests coördinating condenser and vacuum-pump performance have been made by other prominent engineers and it is hoped will become a universal custom. Such vacuum-pump guarantees are not to be confused with the figures of capacity by shop test with free dry air; reference is had here to the actual steam jets that will be used and to the steam consumed when the condenser is either on test or in operation with a definite limit of air leakage.

The principal features of design which contribute to the high efficiency with low air-pump power have been explained in various publications and are summarized as follows:

Shell shape and tube staging
External coolers
Longitudinal control.

The shell shape is shown in Figs. 7 and 11 in combination with the arrangement of tubes. Large flow areas are obtained at the top; small areas and sustained velocities, in direct line without turns, toward the bottom. There is no internal baffling. Fig. 11 shows an arrangement of hotwell, vapor outlet, and cooler. The external air coolers relieve the main condenser of air devapori-

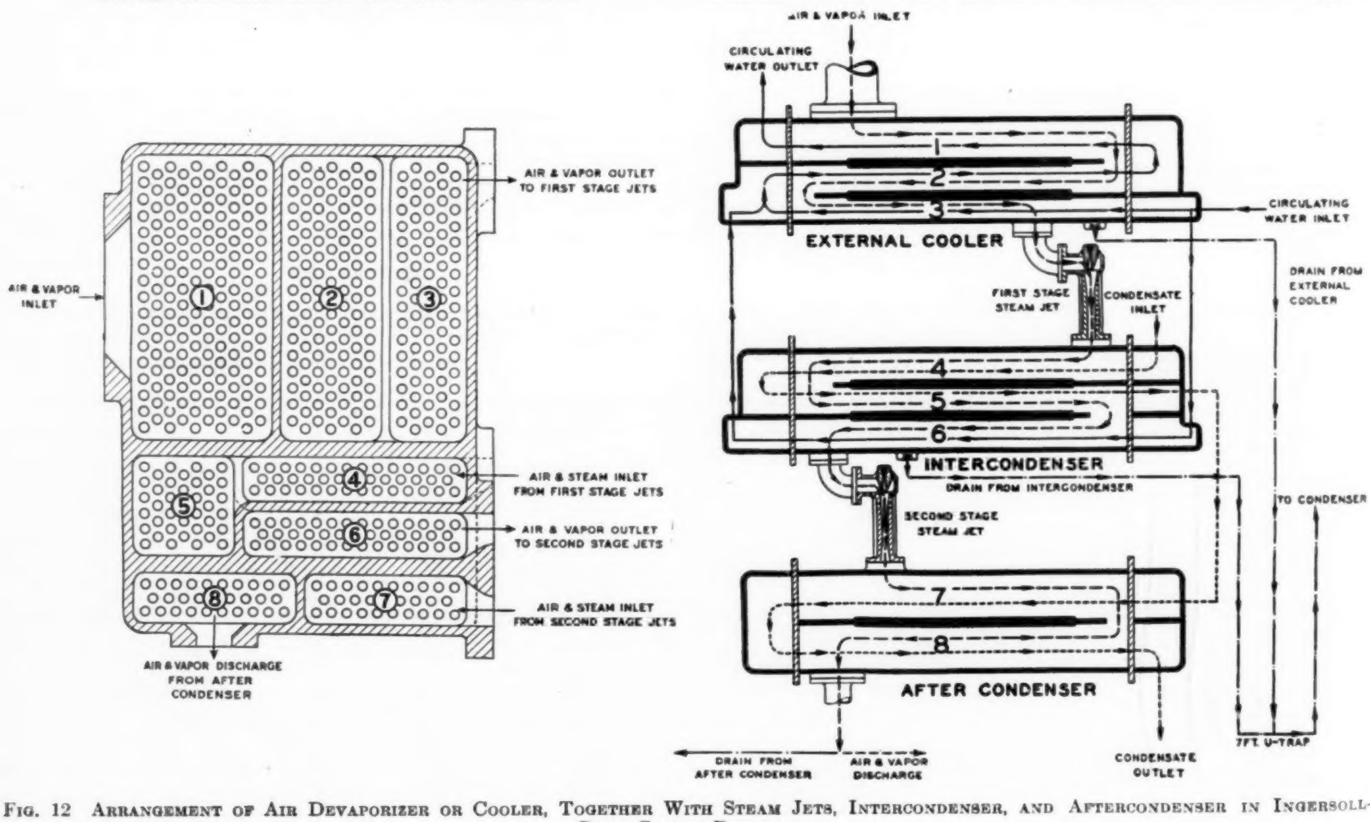


Fig. 12 Arrangement of Air Devaporizer or Cooler, Together With Steam Jets, Intercondenser, and Aftercondenser in Ingersoll-Rand Cooler Design

as is the almost universal custom, is worthless. Such steam quantities when capitalized represent \$15,000 to \$30,000, or enough to buy a whole condenser of fairly large size, adding a corresponding amount to the area and nullifying the usefulness of the coefficient as a measure of work done per unit of investment. The heat-transfer coefficient is a derived or secondary result and has its full significance only when embodied in a complete test report as given in the A.S.M.E. Test Code.

Table 1 gives the actual steam-jet steam used in operation and corresponding to the condenser results shown in the various charts. The condensers have been operated with less jet steam; the quantities shown being those actually used under the local conditions of operating personnel, arrangement of elements, etc.

zation. Shrinking a steam-air mixture is a difficult process best performed in a separate apparatus. Fig. 12 shows a cooler combined with steam jets. Figs. 13 and 14 show how longitudinal control is obtained.

The interest shown in longitudinal distribution warrants a brief explanation. The condenser in large sizes is divided into four compartments by tight support sheets. Condensate is trapped to prevent flashing, and vapor and air are removed at different vacuums corresponding to the pressure-drop requirements in each section. Each pair of vapor outlets is connected to one of two coolers and the primary steam jets on these operate at different vacuums. Between the two outlets of a pair, control is secured by an orifice plate located in the outlet which it is desired to choke.

Fig. 15 shows the relative steam loads and pressure drops along the length of a condenser. As the inlet end has the colder water, it has greater condensing capacity than the discharge end. Comparing the first 2-ft. section of a condenser with the eleventh or last 2-ft. section of a 22-ft. condenser, the relative capacities and pressure drops in a typical case are:

	First section	Eleventh section
Condensing capacity	1.88	1.00
Pressure drop (square)	3.50	1.00

Three and one-half times the pressure is required in the first section as against the eleventh. To these requirements as to pressure drops must be added the effect of impact or lack of impact of the incoming steam, depending on size and arrangement of turbine exhaust.

It is apparent that unless adequate provision is made in the construction of the condenser and the air-removal system, the steam cannot be expected to penetrate completely except at the hot end of the condenser. In the remaining parts there will be varying degrees of penetration with corresponding waste of surface throughout the bottom. These conditions prevail even when a wedge-shaped shell is used and the air cooling is done externally.

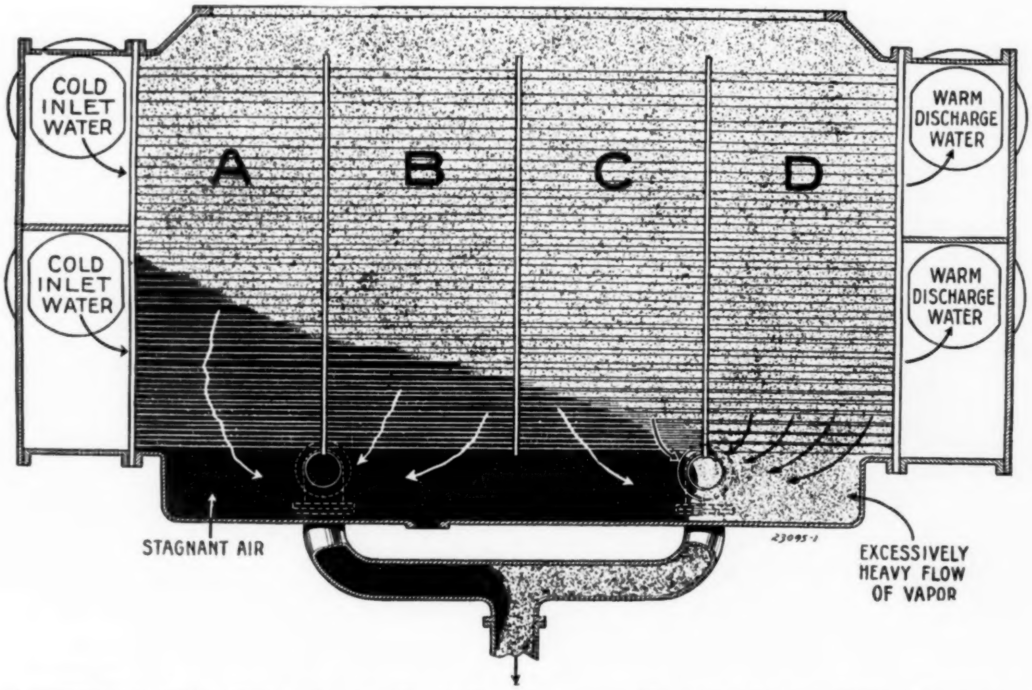


FIG. 13 FAULTY LONGITUDINAL STEAM DISTRIBUTION IN SINGLE-PASS CONDENSER WHEN THE VACUUM PUMP MAINTAINS THE SAME VACUUM UNDER ALL SECTIONS

(The vapors from section *D* are, in effect, a short-circuit to the vacuum pump, while the bottoms of the other sections are surrounded by stagnant air.)

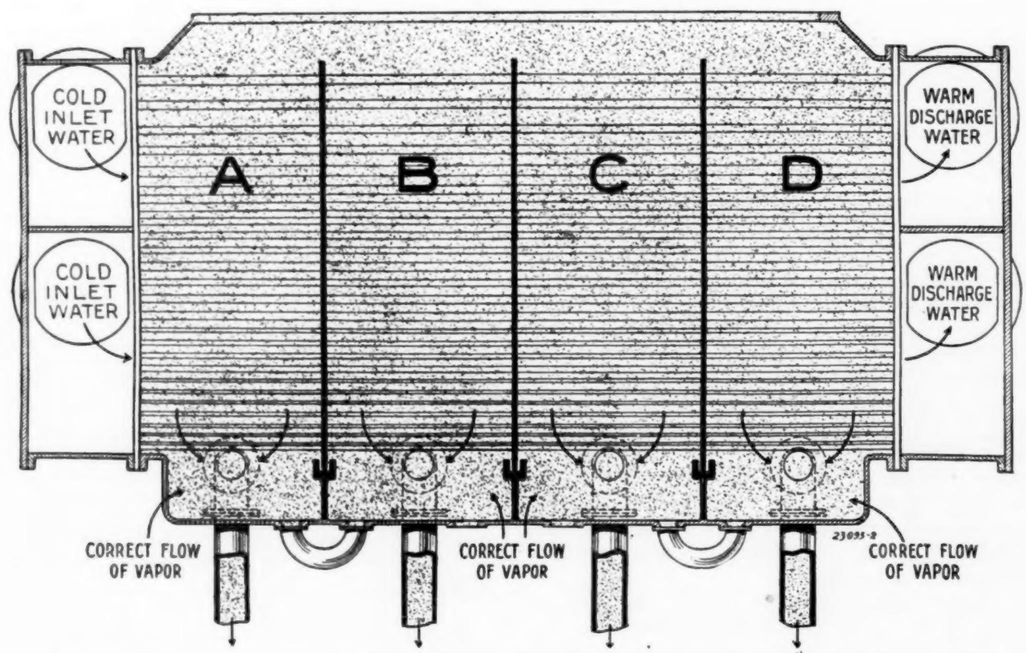


FIG. 14 CORRECT LONGITUDINAL STEAM DISTRIBUTION IN AN INGERSOLL-RAND SURFACE CONDENSER

(Each section is made, in effect, a separate condenser by steam-tight support plates. Because each section has its separate vapor outlet, a different and suitable vacuum can be maintained under each section.)

SINGLE-PASSING

If a condenser is not efficient, with the result that there are large numbers of tubes which are wasted and with corresponding

waste of water, the condenser had better be of the two-pass type, giving the water a second chance to be heated. It is axiomatic that the less efficient a condenser or water heater, the more times the water must be passed back and forth in order for it to do its work.

Assume a condenser with only 20 per cent of waste tubes and water, this being far from an unfavorable assumption.[4] If this

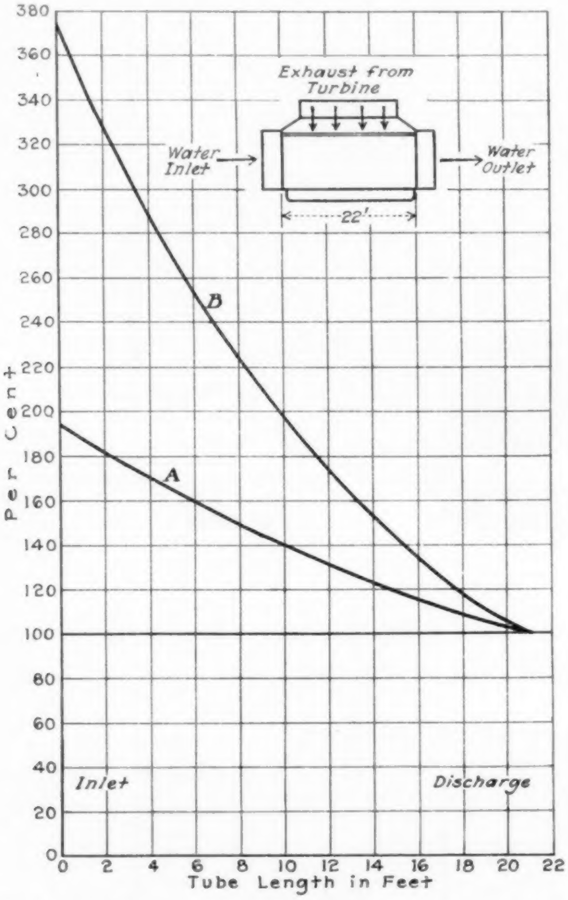


Fig. 15 Line *A* Shows the Relative Steam Load Along the Length of a 22-Ft. Condenser in Order to Give Equal Activity Throughout the Depth in All Longitudinal Sections of the Condenser. The First 2-Ft. Section Must Condense 185 Per Cent as Much Steam as the Last or 11th 2-Ft. Section. Line *B* Shows the Necessary Pressure Drops to Insure Flow of the Steam Quantities Indicated by *A*

is a single-pass condenser, it will require 25 per cent more surface and 25 per cent more water than an efficient condenser. The additional water adds 25 per cent to the pump power and cost of piping and tunnels.[5]

The water can be slowed down to the normal quantity, but this will reduce the condenser capacity so that more surface will be needed. This, however, means more tubes and will reduce the velocity still further, with corresponding reduction in coefficient. The result is shown in Fig. 16. To obtain the same capacity 100 per cent more surface is needed.

This surprising result is due to the handicap of only 20 per cent waste tubes and water; there is only 80 per cent water to do all the work, calling for greater actual temperature rise and more and more surface with corresponding lower velocities, all of which finally comes to a balance as shown. Such a condenser had better be made of the two-pass type; and, conversely it is only when waste tubes are eliminated that condensers of the single-pass type are justified.

[4] In the September, 1924 N.E.L.A. Report, p. 12, tests are reported showing very small relative rise in the first pass of a two-pass condenser and indicating between $^1/_5$ and $^1/_{10}$ the efficiency of heat transfer for the first half of the surface as against the second half. This corresponds to about 40 per cent waste surface.

[5] Various means of choking this waste water such as valves, multiple-passing, or using smaller tubes were described some years ago and are covered in various patents.

Appendix No. 1

STRAIGHT-LINE LAW

By referring to the fundamental equation of heat transfer from steam to water in a tube, it will be seen that the ratio of the temperatures

$$\frac{\text{Steam} - \text{cold water}}{\text{Steam} - \text{hot water}} = \text{Constant}$$

for any given condition of water flow and coefficient of heat transmission as determined by physical factors such as material of tube, speed of water, etc.[6] It follows by algebraic transformation that the ratio of the temperatures

$$\frac{\text{Hot water} - \text{cold water}}{\text{Steam} - \text{cold water}} = \text{Constant, also.}$$

As the difference of the hot and cold water is the rise in temperature or load, it follows that the load plotted against the temperature difference is a straight line. This temperature difference is not the mean temperature difference but simply the difference of steam and cold injection water.

This law is true for a single tube supplied with fixed water quantity; at some other quantity or for some other tube the line is straight but at another slope. A condenser, made up of many tubes, should follow the same law. Actually it departs more or less from this law, the reason being that the performance of a single tube is controlled by thermal conditions whereas that of a condenser is influenced by flow and distribution forces

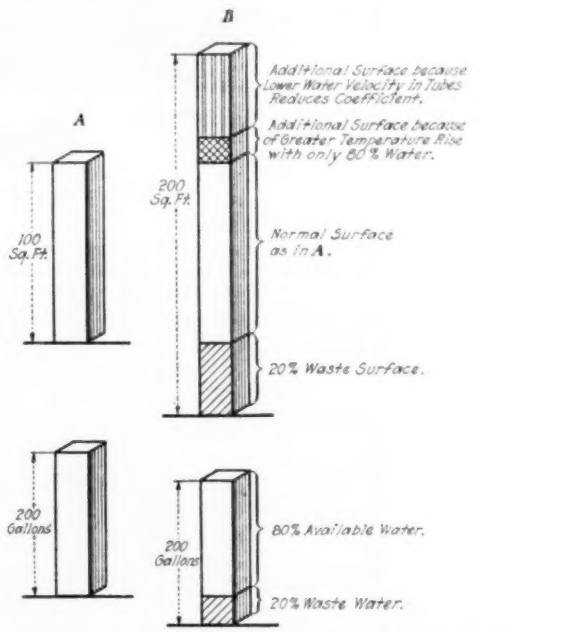


Fig. 16 Effect of Waste Tubes in a Single-Pass Condenser as Compared to a Condenser Having All of Its Tubes Active and Therefore Using All of Its Water

(20 per cent waste of surface and water, as shown in *E*, necessitates a single-pass condenser of twice the size to do the same work with the same total water quantity as in *A*.)

as well. The flow conditions in turn are determined by steam volume, air leakage, capacity of the vacuum pump, and condenser design—particularly flow conditions through the tube banks and provisions for air devaporization. These have a complex influence on performance, which need not be discussed. The usefulness of the straight-line law lies in the fact that it is convenient for plotting, a straight edge being employed, and that it defines the regions of departure from the theoretical and best performances.

If titanium nitride powder be applied to the surface of foundry molds and cores, and especially to those employed in the casting of steel, the nitride gives to these surfaces a high resistance to the molten metal so that the molding sand is prevented from burning into or uniting with the liquid steel. Very little nitride is required, but the facing must be uniform and must completely cover the surface of the mold. As the steel cools in the mold the hard nitride gradually oxidizes to the soft fluffy dioxide. During the oxidation nitrogen gas is slowly liberated and forms a protecting film so that the steel maintains a bright, unscaled surface.—*The Engineer* (London), January 14, 1927, p. 45.

[6] See Hirshfeld & Barnard's Elements of Heat-Power Engineering, p. 463.

Steam-Condenser Practice and Performance

By F. J. CHATEL,[1] DETROIT, MICH.

This paper presents a general idea of steam-condenser practice and performance in the four plants of the Detroit Edison Company. The condenser performances from the time of the original installations down to the present show a marked improvement. This indicates that condensers of the single-pass type with a range of from 0.95 to 1.05 sq. ft. of surface per kilowatt of turbine capacity should be considered good practice. Their performance seems to outweigh the fact that a somewhat larger amount of water is necessary for this type than for a two-pass condenser or a condenser having more tube surface.

For convenience, the four plants mentioned in this discussion of steam-condenser practice will be lettered alphabetically according to their ages, the oldest plant being referred to as plant A.

Installations

Tabulated data for all condensers and their circulating pumps are given in Table 1. Condensers 1 to 9 in plant A are of the double two-pass type designed to accommodate the step bearings of vertical turbines. All other installations are operating in connection with horizontal turbines. It should be noted that the newest installations, No. 2 at plant C and Nos. 1, 2, and 3 at plant D, have an average ratio of less than one square foot of cooling surface per kilowatt of turbine capacity. These condensers, as well as the two 70,000-sq. ft. condensers at plant B and the 35,000-sq. ft. condenser at plant C, are of the one-pass type. This was done with the object of obtaining the highest vacuum possible at the expense of an increased amount of circulating water passed through the condensers, and does not necessarily imply that the company is prepared to say that any one type is superior to the other, everthing considered. One-inch No. 18 gage tubes are used at all plants. A metallurgical study of tube composition was made in 1914, from which it was found that, with specified grain structures, tubes of 70 per cent copper and 30 per cent zinc, or, as a slight variant, Admiralty metal, were best suited for Great Lakes water conditions. The tubes installed in condensers 1 to 9 of plant A prior to this study gave considerable trouble at first due to splitting and were removed for heat treatment. Practically no troubles have been encountered with these older tubes since they were heat-treated.

All condensers have circulating pumps driven by adjustable-speed motors, with the exception of Nos. 1 to 9 in plant A, where Nos. 1 to 4 are driven by alternating-current motors, and Nos. 6 to 9 by steam engines.

Dry vacuum pumps are of the reciprocating two-stage, single-acting type, and are driven by adjustable-speed motors, excepting the earlier installations, Nos. 1 to 9 in plant A, where they are driven by steam engines.

Figs. 1 to 9 show the different types of tube layouts at the four plants. The solid circles indicate plugged holes in the tube sheets, the tubes being omitted to provide steam lanes, and to accommodate drain plates and drain pipes. Fig. 10 is a front elevation of condensers 1, 2, and 3, plant D, and is included to show the location of the gates.

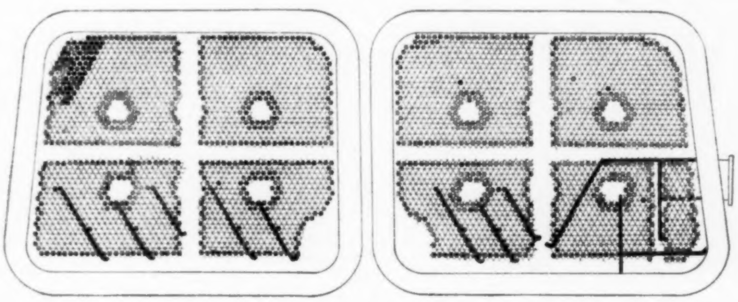


Fig. 1 Condenser No. 1, Plant A. Tube-Sheet Layout of the 16,000-Sq. Ft. Condenser Showing Steam Lanes and Drain Plates

Fig. 1 shows the tube-sheet layout of No. 1 condenser in plant A. This is a double two-pass condenser and is similar in design to the others operating with the vertical turbines. The solid circles indicate the location of baffles in the lower half of the condenser. The tubes in the upper left-hand corner were removed to improve steam-entrance conditions. The open sections near the centers of the four panels are for staybolts in the water boxes. About 10 per cent of the tubes of these condensers are in the air coolers.

Fig. 2 shows the outline of the eccentric shell and the tube-sheet layout of No. 10 at plant A and No. 8 at plant B. In the upper

TABLE 1 MAIN CONDENSERS AND CIRCULATORS

Condensers															Circulating pumps						
												Tube composition								Motors	
Plant	Cond. No.	Put in service	Max. turbo-generator cap., kw.	Max. possible cooling surface, sq. ft.	Cooling surface in service at time of tests, sq. ft.	Sq. ft. surface per kw. turbine cap.	No. of passes	No. tubes installed	Length tubes bet. tube sheets	Gage of tubes	Tube sheet diam.	Cu.	Zn.	Sn.	Number	Size, in.	Estimated head, ft. (max.)	R.p.m. (max.)	Capacity, one pump, G.p.m.	Type	Hp.
A	1	1912	9000	16000	16000	1.78	2	3624	17' 3"	18	......	63	37	..	1	24	22	720	17000	a. c.	150
A	2	1912	9000	16000	16000	1.78	2	3624	17' 3"	18	......	63	37	..	1	24	22	720	17000	a. c.	150
A	3	1911	9000	16000	16000	1.78	2	3624	17' 3"	18	......	63	37	..	1	24	22	720	17000	a. c.	150
A	4	1911	9000	16000	16000	1.78	2	3624	17' 3"	18	......	63	37	..	1	24	22	720	17000	a. c.	150
A	6	1909	14000	25000	25000	1.79	2	6028	16'	18	......	63	37	..	1	30	20	250	25000	steam	210
A	7	1910	14000	25000	24332	1.74	2	5851	16'	18	......	63	37	..	1	30	20	250	25000	steam	210
A	8	1911	14000	25000	24475	1.75	2	4912	16'	18	......	63	37	..	1	30	20	250	25000	steam	210
A	9	1913	15000	22500	22456	1.48	2	5017	17'	18	......	60	40	..	1	30	26	250	30000	steam	300
A	10	1920	30000	42700	39617	1.32	2	8407	18'	18	15' 0"	70	30	..	2	36	23	440	30000	d. c.	300
B	1	1915	20000	35000	32500	1.625	2	6791	18' 3$\frac{3}{8}$"	18	14' 6"	70	30	..	1	42	16	360	36000	d. c.	250
B	2	1915	20000	35000	32487	1.624	2	6894	18' 3$\frac{3}{8}$"	18	14' 6"	70	30	..	1	42	16	360	36000	d. c.	250
B	3	1917	20000	35000	32440	1.622	2	6884	18' 3$\frac{3}{8}$"	18	14' 6"	70	30	..	1	42	16	360	36000	d. c.	250
B	4	1918	45000	70000	59210	1.316	1	9423	24'	18	16' 9"	70	30	..	2	48	..	300	60000	d. c.	450
B	6	1920	45000	70000	64600	1.435	1	10413	23' 8$\frac{3}{4}$"	18	16' 9"	70	30	..	2	48	..	300	60000	d. c.	450
B	8	1920	30000	42700	39660	1.320	2	8416	18'	18	15'	70	30	..	2	36	23	400	30000	d. c.	300
C	1	1922	10000	16300	16300	1.63	2	5294	11' 9$\frac{1}{2}$"	18	10' 10$\frac{1}{2}$"	70	30	..	1	30	26	400	20000	d. c.	182
C	2	1922	30000	35000	29101	0.97	1	5558	20'	18	Rect.	70	30	..	2	36	23	400	40000	d. c.	300
C	3	1923	10000	16300	16300	1.63	2	5294	11' 9$\frac{1}{2}$"	18	10' 10$\frac{1}{2}$"	70	30	..	1	30	26	400	20000	d. c.	182
D	1	1925	50000	52000	47600	0.95	1	7672	23' 8$\frac{3}{4}$"	18	17' 6"	70	29	1	2	48	20	255	60000	d. c.	255
D	2	1924	50000	52000	47300	0.95	1	7614	23' 8$\frac{3}{4}$"	18	17' 6"	70	29	1	2	48	20	255	60000	d. c.	255
D	3	1924	50000	52000	51866	1.04	1	8349	23' 8$\frac{3}{4}$"	18	17' 6"	70	29	1	2	48	20	255	60000	d. c.	255

Tube diameter, 1 in. in all cases.

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half the original steam lanes were widened by omitting outer vertical rows of tubes on four of the tube banks. The lower half is divided into sections with drain plates and spouts extending to

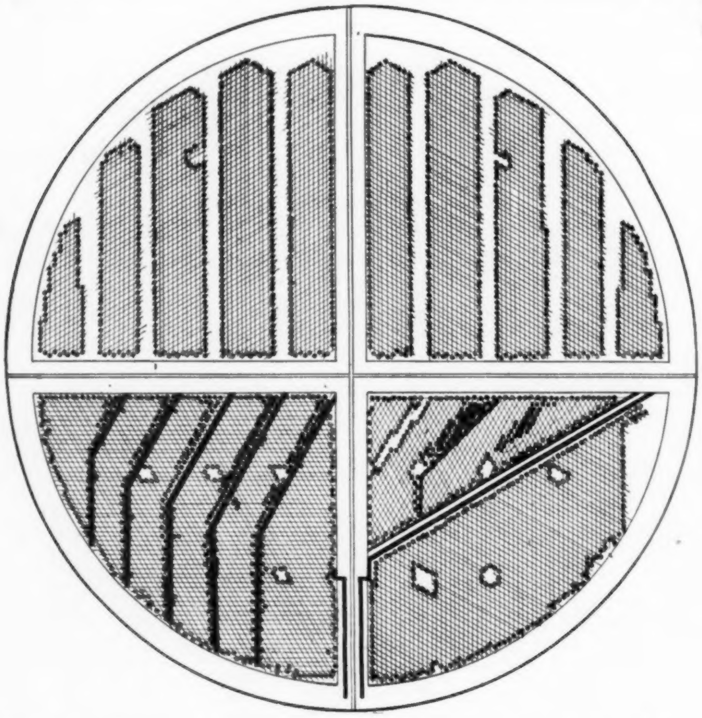

Fig. 2 Condenser No. 10, Plant A, and Condenser No. 8, Plant B. Tube-Sheet Layout of the 42,700-Sq. Ft. Condenser Showing Steam Lanes and Drain Plates

the bottom of the tube sheet in one quarter and to the air-cooler roof in the other quarter. Seventeen per cent of the total number of tubes are in the air coolers of these condensers.

Fig. 3 shows the tube-sheet layout of condensers 1, 2, and 3 at plant B. As indicated by the solid circles, the steam lanes in the upper quarter over the air cooler are but one tube space in width, while the opposite quarter has tube lanes of varying widths. The air cooler contains 6.8 per cent of the tubes.

Figs. 4 and 5 show the tube-sheet layouts of condensers 4 and 6, respectively, at plant B. These are one-pass condensers and have eccentric shells which provide a crescent-shaped steam belt on one side of the tube bundle. They are alike excepting as to the general arrangement of steam lanes and drain plates and the amount of cooling surface actually in service. No. 4 has 15.6 per cent of the tubes in the air cooler, while No. 6 has 14.8 per cent. Baffles are installed in the air coolers, so that the air, taking a zigzag course, will sweep all tubes at a high velocity.

Fig. 6 shows the tube-sheet layout of the two 16,300-sq. ft. condensers operating at plant C in connection with 10,000-kw. turbines. The air coolers are equipped with baffles, and contain 22.6 per cent of the tubes.

No. 2 condenser at plant C, shown in Fig. 7, varies considerably from the other installations mentioned above in that it is rectangular in shape and the lanes between tube banks are wider at the top than at the bottom, giving a decreasing steam space. Tubes have been removed for steam lanes as shown by the solid circles. A "dummy," A, is located between the tubes in the central steam lane near the top of the tube bank. Below this is a series of troughs. The air outlet is near the top, there being 53.1 per cent of the tubes in the air cooler. The bowl-shaped hotwell is exceptionally large and acts as a deaerator.

Fig. 8 is the tube-sheet layout of condenser No. 1, a single-pass condenser at plant D. This condenser and Nos. 2 and 3 at the same plant are the company's latest installations in regular operation at the date of presentation of this paper. The shell is of circular cross-section but with the tube sheets eccentric to the shell, the center of the tube sheets being vertically below the center line of the shell. This provides a crescent-shaped steam belt on both sides of the tube bundle, wide at the top and narrow at the bottom. On one side of this belt, steam is admitted directly to the bottom of the condenser, and reduces undercooling. The flow is controlled by dampers operated from outside the condenser by means of a screw-and-yoke valve mechanism. On the other side of the condenser the crescent-shaped belt is used as an equalizing chamber on the dry-vacuum-pump suction. A baffle is installed tightly against the tube bundle, and air passes through a narrow slot extending the full length of the condenser.

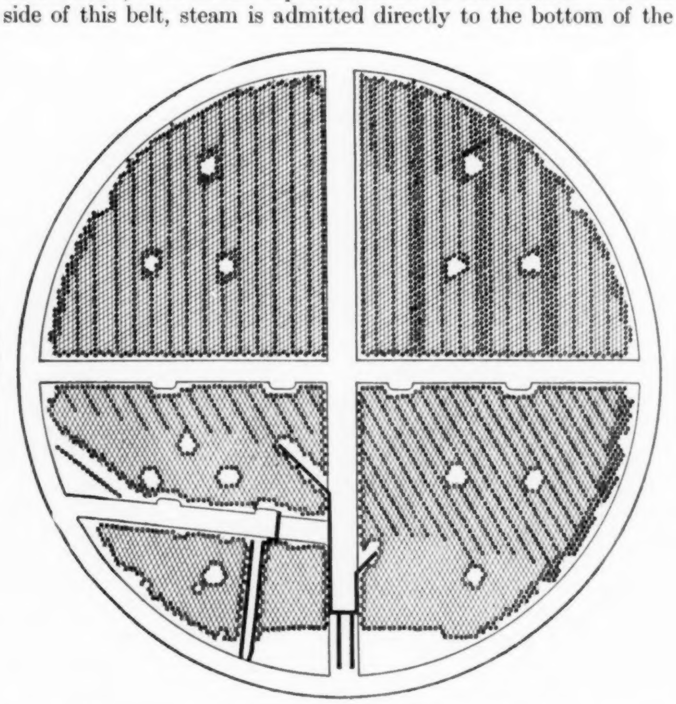

Fig. 3 Condensers Nos. 1, 2, and 3, Plant B. Tube-Sheet Layout of the 35,000-Sq. Ft. Condensers Showing Steam Lanes and Drain Plates

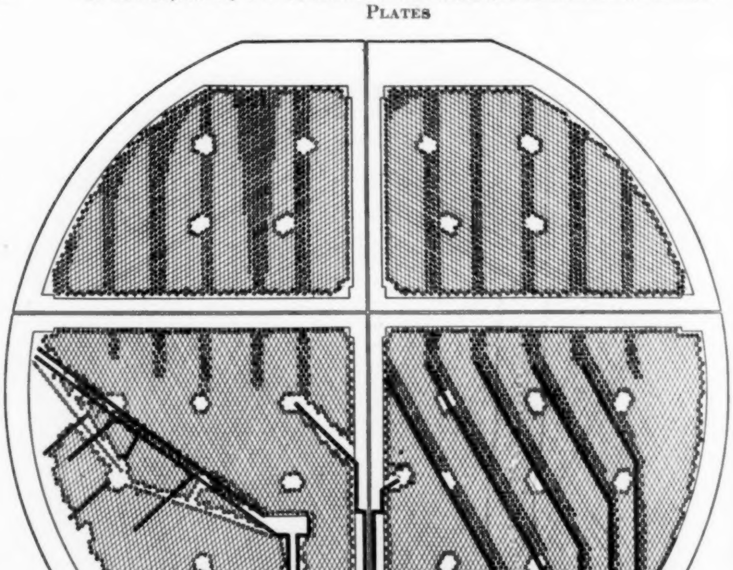

Fig. 4 Condenser No. 4, Plant B. Tube-Sheet Layout of the 70,000-Sq. Ft. Condenser Showing Steam Lanes and Drain Plates

Tubes are arranged along radial lines, the lanes tapering from the top of the condenser to a point near the bottom where the spacing is as close as possible.

Approximately 40 per cent of the condenser is set apart as an air cooler, separated from the steam-condensing section by baffles. In summer, steam sweeps over into this air-cooling section, while in winter condensation is complete before the bottom of the condenser has been reached.

The cast-iron inlet water box is tapered, having greater cross-sectional area at the bottom. Water enters from both circulating pumps through nozzles directed vertically upward, both on the same side of the vertical center line. This directs more water to the top tubes, tending to increase the velocity through them and consequently insure the condensation of a larger amount of steam in this part of the condenser.

A cast-iron water box on the discharge side is provided with an overflow dam and two sets of butterfly valves located in the horizontal partition. By means of these valves, operable from outside the condenser, a portion of the tube surface in the lower part of the shell may be partially shut off from the passage of circulating water in winter.

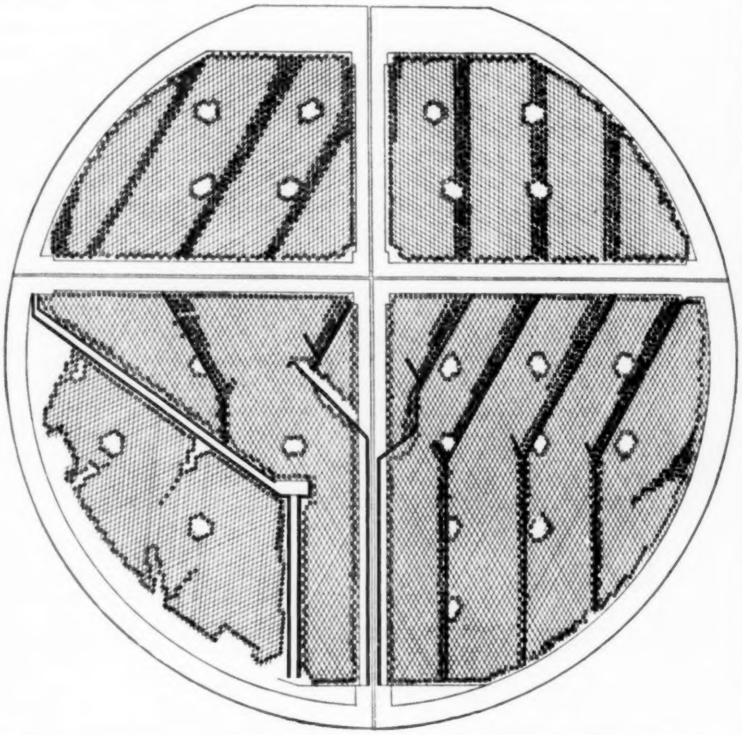

Fig. 5 Condenser No. 6, Plant B. Tube-Sheet Layout of the 70,000-Sq. Ft. Condenser Showing Steam Lanes and Drain Plates

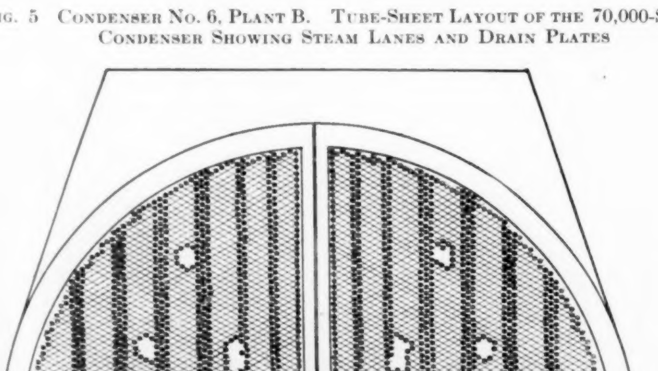

Fig. 6 Condensers Nos. 1 and 3, Plant C. Tube-Sheet Layout of the 16,300-Sq. Ft. Condenser Showing Steam Lanes and Drain Plates

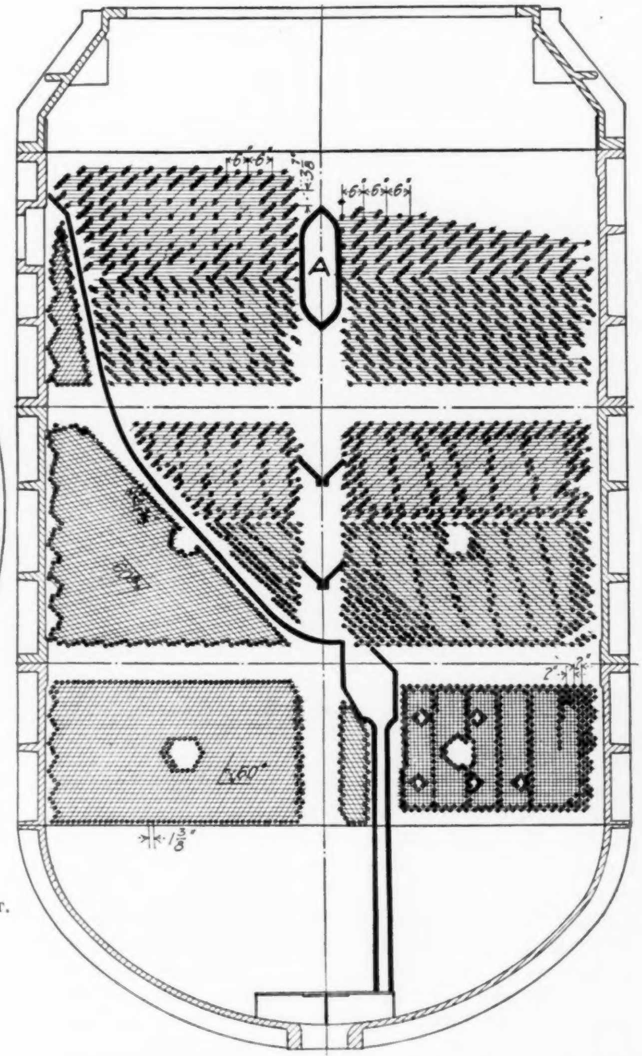

Fig. 7 Condenser No. 2, Plant C. Tube-Sheet Layout Showing Steam Lanes and Drain Plates

Two new condenser installations were completed and put into operation in October, 1926. One was installed for a 30,000-kw. turbine at plant C and the other for a 50,000-kw. turbine at plant D. No tests have as yet been made on these condensers.

Condenser Cleaning

Plant A is the only one of the four plants cleaning condenser tubes by means of "baking," as explained in a later paragraph. Plants B and D use cylindrical rubber plugs as scrubbers, while plant C uses for the same purpose disks of sheet-rubber packing $^1/_8$ in. thick and slightly larger than the tube diameter. A nail is driven through the center of these disks to prevent their tipping over. These, like the cylindrical plugs, are forced through with general-service water at 100 lb. per sq. in. pressure.

In baking, such as is being done at plant A, the condenser is drained and the dry vacuum pump operated to maintain low vacuum. The priming valve between water box and steam space is cracked to allow any steam generated in the tubes to be drawn into the steam space. Steam is admitted through the turbine-throttle by-pass

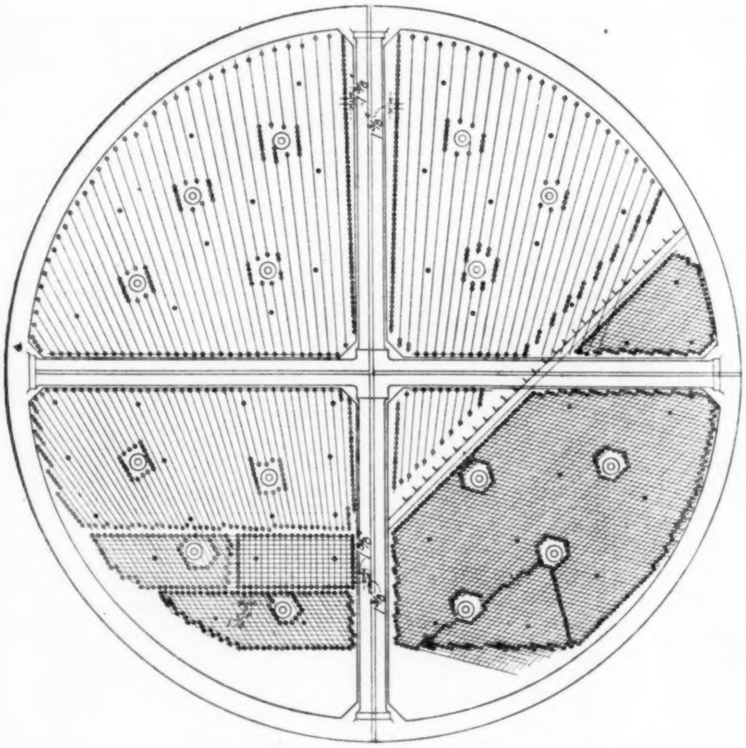

FIG. 8 CONDENSERS NOS. 1, 2, AND 3, PLANT D. TUBE-SHEET LAYOUT OF THE 52,000-SQ. FT. CONDENSER SHOWING STEAM LANES AND DRAIN PLATES

valve in quantities sufficient to maintain an average temperature of 185 deg. fahr. at the air-pump suction. This is maintained for a period of five hours. Due to the design of the condensers under the vertical turbines, they are baked with the turbines turning obtain better steam distribution. This is not necessary with the horizontal turbine. After baking, the condenser is allowed to cool for a half-hour, and is flushed with cooling water. The deposit in the tubes is a rather soft scale which flakes up close to the metal in the process of baking and is carried out by flushing. The condenser is again drained and tested for leaks, under vacuum, by means of a torch passed over the tube ends. No injurious results have developed to date from this method of cleaning. Comparatively few tubes are found leaking and no troubles due to temperature changes have been encountered. Fiber and canvas rings are used for tube packing. Baking has a decided advantage over the other methods of cleaning in that it does not cripple the unit so long, and reduces the labor charges. About 9000 lb. of steam and 80 kw-hr. of auxiliary energy are required to bake a 42,700-sq. ft. condenser, whereas it takes four men about twelve hours to shoot plugs through a condenser of equal size. Daily observations of the condenser performance must be made to determine the "between-cleaning" periods. In summer the back pressure will climb rapidly enough to warrant cleaning weekly, particularly at plants A and B where the circulating water contains the highest percentage of oil and organic matter. At plant A, curves representing various loads are plotted with circulating-water temperature and minimum back pressure as coördinates. The back pressure and water temperature were obtained from the log sheets covering the period of one year. All the data were taken within a day after cleaning, so that the curves represent the best possible conditions. A back pressure obtained at any time can be compared with the back pressure obtainable with a clean condenser at any given circulating-water temperature. A condenser is considered ready for baking when the back pressure is 0.25 in. Hg higher than the back pressure shown on the curves referred to above. Back pressures before and after cleaning No. 10 at plant A and No. 8 at plant B are plotted against load for both summer and winter conditions are shown in Fig. 11. This shows clearly the results before and after cleaning, with plugs in No. 8 condenser at plant B and baking No. 10 at plant A. Fig. 12 shows the heat-transfer coefficients plotted against load for No. 10 at plant A. The heat transfer rises, while the back pressure decreases, a condition which, under similar operating conditions, can only exist with an improvement in the condenser, either in cleanliness or design.

Comparing these sets of curves, it is evident that the drop in back pressure due to cleaning is very pronounced, but the back pressures of No. 8, plant B, either before or after cleaning are relatively higher than those of No. 10, plant A. This indicates that the tubes do not reach the same degree of cleanliness, as the condensers are of the same size. These results, however, do not take circulating-water temperature rise and pounds of condensate into account, but No. 10 turbine at plant A receives initial steam at a lower temperature and pressure and consequently has a higher water rate. Both have adjustable-speed motor-driven circulating pumps, making it possible to regulate their speeds to obtain the proper circulating-water temperature rise.

PERFORMANCE

As a means of comparing condensers of different sizes and designs it was decided to draw curves of heat-transfer coefficient and back pressure plotted against circulating water per pound of condensate per thousand square feet of cooling surface. These items were chosen as the major dependent and independent variables indicating the performance of a condenser. Other results collateral to the above which must be considered are the amount of air in the

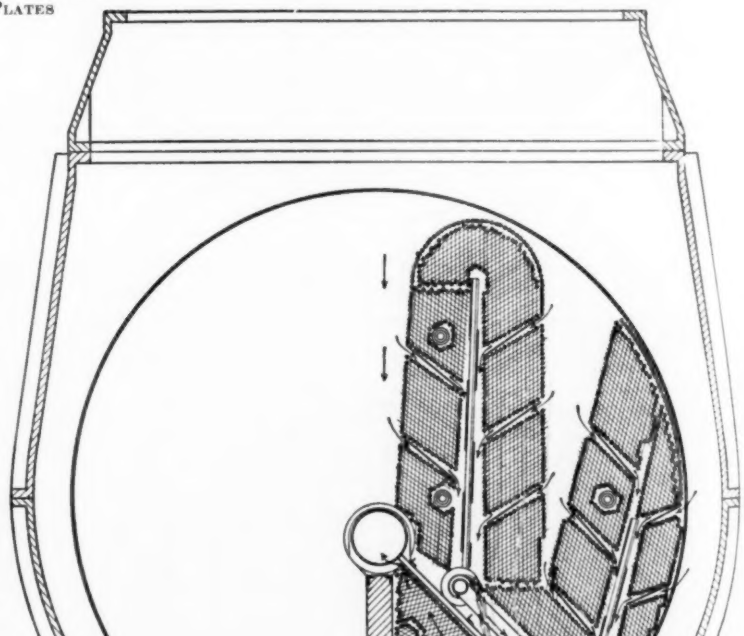

FIG. 9 CONDENSER NO. 4, PLANT D. TUBE SHEET LAYOUT OF THE 52,000-SQ. FT. CONDENSER SHOWING STEAM LANES AND DRAIN PLATES

steam, the auxiliary input, undercooling of the condensate, temperature of the circulating water, and cleanliness of the tubes. The effect of variations in the last two factors can be eliminated by testing condensers with clean tubes and comparing runs with like circulating-water temperatures.

The amount of circulating water which has to be passed through a condenser to condense a pound of steam depends largely upon the design of the condenser, and is an indication of the ability of the unit as a whole to do its work, that is, to condense steam and create a vacuum. This indication, however, is not decisive, for a condenser may have an excessive amount of cooling surface and would appear very efficient if the surface were not taken into account. The circulating water per pound of condensate, then, should be based on a unit of surface. The performance of condensers of different sizes and designs can be compared when referred to unit surface.

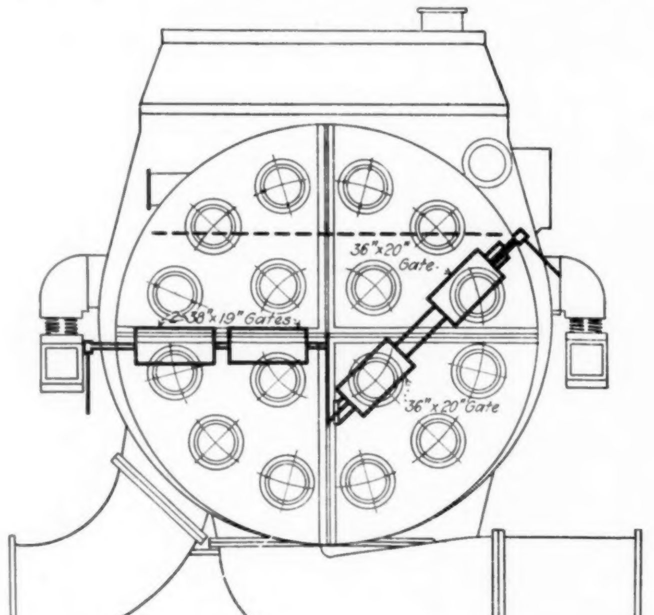

Fig. 10 Condensers Nos. 1, 2, and 3, Plant D. Front Elevation of the 52,000-Sq. Ft. Condenser

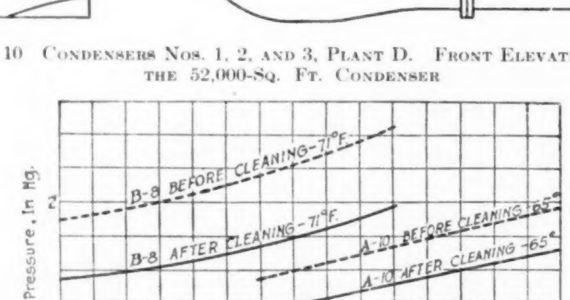

Fig. 11 Effect of Cleaning on Back Pressures. The Temperatures Shown Are Those of Circulating Water

The coefficient of heat transfer should be considered as one of the coördinates because it is one of the variables dependent upon the quantities mentioned above. It represents the rate of heat absorption or the ability of the condenser to absorb heat per square foot of surface under given conditions.

The back pressure also must be considered, as a high heat-transfer coefficient does not mean a low back pressure. A high heat-transfer coefficient and low back pressure are the two resultant quantities desired. With no condenser alterations the heat-transfer coefficient and back pressure will vary directly, and so, in comparing different condensers, both items must be considered.

These data, taken in conjunction with the circulator input, undercooling of the condensate, and the air in the steam, will involve all major factors affecting the performance.

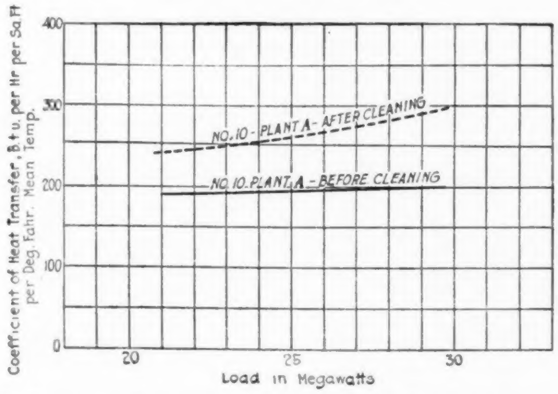

Fig. 12 Effect of Cleaning on Heat-Transfer Coefficient of No. 10 Condenser at Plant A

(The heat-transfer coefficient after cleaning is shown by the dotted curve, while the condition before cleaning is indicated by the solid curve. The circulating-water temperature was 32 deg. fahr.)

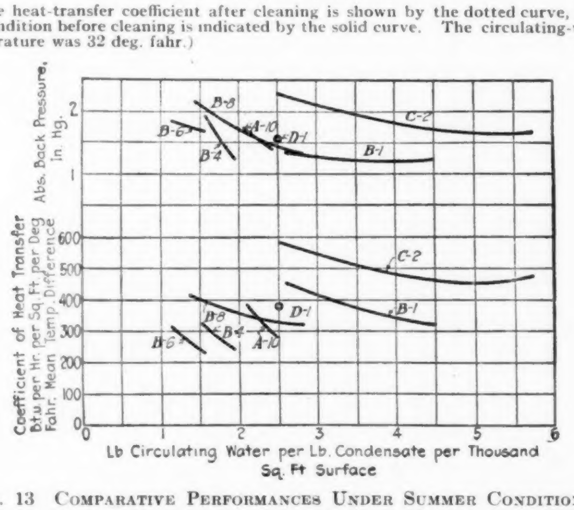

Fig. 13 Comparative Performances Under Summer Conditions

(The letters and figures indicate the plant and condenser. The circulating-water temperatures are as follows: A-10 = 64 deg. fahr.; B-1 = 67 deg. fahr.; B-4 = 73 deg. fahr.; B-6 = 76 deg. fahr.; B-8 = 66 deg. fahr.; C-2 = 70 deg. fahr.; D-1 = 73 deg. fahr.)

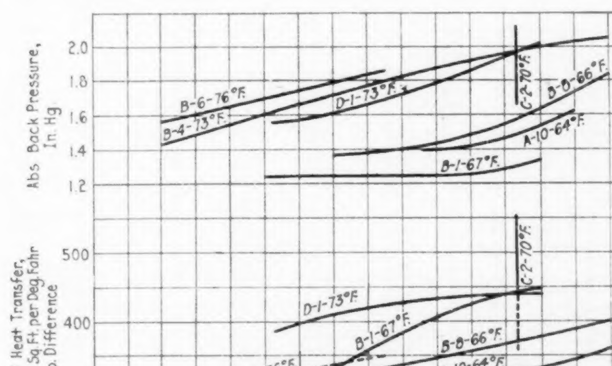

Fig. 13-A Comparative Performances Under Summer Conditions

(Back pressures and heat-transfer coefficients based on per cent of rated capacity of turbo-generators.
Dotted lines indicate heat-transfer coefficients for C-2 and B-6 with the mean temperature difference computed by the logarithmic formula. Solid lines for C-2 and B-6 indicate heat transfers computed by the arithmetical mean temperature difference.
The letters and figures indicate the plant, condenser and inlet circulating-water temperatures.)

On Figs. 13 and 14 heat-transfer coefficients and back pressures have been plotted against pounds of circulating water per pound of condensate per thousand square feet of cooling surface

for summer and winter conditions; and on Figs. 13-A and 14-A against per cent of rated capacity of the turbo-generator. Data have been taken from special tests in all cases except in the case of condenser A-10, for which data were taken from operating records. Unfortunately test results could not be obtained with the same inlet circulating water temperatures in all cases, and in several of the tests air quantities removed were not measured. Air quantities measured in several condenser tests show an average range of from 4 to 8 cu. ft. per min. Fig. 15 shows the percentage of main turbo-generator output used by the circulating pumps, and Fig. 16 the undercooling of the condensate. Both are plotted against circulating water per pound of condensate per thousand square feet of cooling surface.

Discussion of Data

From the curves on Figs. 13 to 16, inclusive, and the data in Tables 1 and 2 it is possible to obtain an idea as to the relative merits of condensers. As an example, it is readily seen that No. C-2, although having a high rate of heat transfer, also has a high back pressure and gives less satisfactory results than the remaining condensers. Its abscissas are large quantities as compared with the others, with the exception of B-1. This is due to the small cooling surface, 0.97 sq. ft. per kilowatt of turbine capacity, resulting in a large ratio of circulating water per pound of condensate. The circulating-pump power input is not abnormally high, but, on the other hand, undercooling of the condensate averages higher than the other installations.

Condenser B-1 although having large abscissas, operates with satisfactory heat-transfer coefficients and back pressures. Since it has a large amount of surface, 1.59 sq. ft. per kilowatt of turbine capacity, it is evident that the quantity of circulating water per pound of condensate must be large. Its circulating-pump input is not abnormally large, but the undercooling is high during winter operation.

The remaining curves, having smaller abscissas, indicate more surface per kilowatt of capacity or less cooling water per pound of

TABLE 2 CONDENSER DATA AND RESULTS

Plant	Cond. No.	Fig. No.	Test run No.	Abs. press., in. Hg. steam entering cond.	Abs. press., in. Hg. steam at hotwell	Abs. press., in. Hg. steam at air-cooler outlet	Temp., °F. circulating water entering	Circulating-water temp. rise, °F.	Condensate temperature, °F.	Lb. condensate per sq. ft. cooling surface per hr.	Lb. circulating water per lb. condensate	Lb. circulating water per lb. condensate per 1000 sq. ft. cooling surface	Heat-transfer coeff., B.t.u./hr./sq. ft./°F. mean temp. D.	Undercooling of condensate, °F.	Quantity of air removed, cu. ft. per min. at 32 deg. fahr. and 29.92 in. Hg.	Power input to circulating pumps, Kw.	Turbo-generator Megawatts	Percentage turbo-generator output used by circulating pumps
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	10	2	1	1.04	....	....	32.0	13.5	80.0	8.33	73.8	1.86	200.6	....	....	580.0	29.7	1.95
A	10	2	2	0.86	....	....	32.0	12.0	76.0	7.38	83.0	2.09	199.0	....	....	588.0	26.8	2.19
A	10	2	3	0.66	....	....	32.0	10.0	68.0	5.68	100.2	2.57	189.5	....	....	496.0	21.0	2.36
A	10	2	4	0.67	....	....	32.0	15.5	70.0	8.28	64.5	1.63	298.0	....	....	410.0	29.8	1.375
A	10	2	5	0.57	....	....	32.0	13.5	68.0	6.74	74.9	1.89	259.5	....	....	368.0	24.7	1.49
A	10	2	6	0.49	....	....	32.3	11.0	65.0	5.52	90.9	2.29	243.2	....	....	326.0	20.8	1.57
A	10	2	7	1.92	....	....	64.0	13.5	101.0	8.68	72.8	1.84	294.0	....	....	588.0	28.9	2.04
A	10	2	8	1.73	....	....	64.0	12.0	98.0	7.23	82.1	2.07	267.6	....	....	588.0	24.7	2.38
A	10	2	9	1.58	....	....	64.0	11.0	95.0	6.19	89.7	2.26	253.0	....	....	572.0	21.5	2.66
A	10	2	10	1.67	....	....	65.0	11.5	98.0	8.44	85.7	2.16	329.0	....	....	588.0	28.8	2.04
A	10	2	11	1.43	....	....	64.0	11.2	91.0	6.82	88.3	2.23	330.0	....	....	556.0	23.9	2.32
A	10	2	12	1.43	....	....	65.0	10.5	92.0	6.22	94.1	2.37	304.0	....	....	452.0	21.8	2.07
B	8	2	1	1.27	....	....	66.0	9.5	83.5	4.57	104.7	2.64	317.2	3.0	....	213.5	15.8	1.35
B	8	2	2	1.34	....	....	66.3	10.9	85.0	4.56	91.2	2.30	310.0	3.1	....	144.9	15.6	[illegible]
B	8	2	3	1.45	....	....	66.5	12.3	86.5	4.54	80.8	2.04	282.6	4.1	....	104.2	15.2	[illegible]
B	8	2	4	1.37	....	....	65.0	9.5	84.5	6.22	104.8	2.64	352.6	4.3	....	409.7	22.4	1.68
B	8	2	5	1.43	....	....	65.0	11.0	86.0	6.22	90.4	2.68	347.7	4.2	....	276.8	22.4	1.27
B	8	2	6	1.51	....	....	65.5	12.5	87.5	6.22	79.5	2.00	347.8	4.4	....	196.8	22.4	0.88
B	8	2	7	1.87	....	....	67.5	12.1	91.0	9.19	82.1	2.07	432.2	8.0	....	435.0	31.4	[illegible]
B	8	2	8	2.00	....	....	68.0	13.8	92.5	9.16	72.0	1.82	408.1	8.6	....	288.0	31.2	[illegible]
B	8	2	9	2.20	....	....	68.0	17.0	95.5	9.16	58.3	1.47	393.0	8.9	....	196.0	31.0	0.63
B	1	3	6	0.61	0.63	0.64	32.7	9.3	50.0	3.58	114.7	3.53	131.8	14.5	....	133.6	10.0	1.34
B	1	3	1	0.46	0.50	0.44	32.8	10.2	49.6	4.49	105.3	3.24	208.2	6.9	....	138.0	13.0	1.06
B	1	3	2-A	0.55	0.58	0.64	32.5	11.4	52.2	4.81	93.2	2.87	220.1	9.3	....	138.7	14.0	0.99
B	1	3	2-B	0.56	0.62	0.61	32.6	9.9	51.7	4.81	108.1	4.81	215.0	10.3	....	139.5	14.0	1.00
B	1	3	2-C	0.55	0.58	0.57	32.6	6.4	48.7	4.81	166.6	5.13	187.4	12.8	....	189.8	14.0	1.36
B	1	3	3-A	0.61	0.54	0.52	32.7	12.3	52.0	5.43	85.8	2.64	250.8	12.5	....	138.7	16.0	0.87
B	1	3	3-B	0.59	0.51	0.49	32.7	10.3	50.0	5.43	103.3	3.18	225.5	13.5	....	154.5	16.0	0.97
B	1	3	3-C	0.58	0.55	0.51	32.7	6.3	48.5	5.43	168.1	5.18	213.5	14.5	....	189.8	16.0	1.19
B	1	3	7-A	0.63	0.59	0.52	32.7	15.1	54.2	6.10	70.3	2.16	266.4	11.3	....	138.7	18.0	0.77
B	1	3	7-B	0.60	0.56	0.57	32.7	11.3	52.0	6.10	94.2	2.90	259.0	12.0	....	160.5	18.0	0.81
B	1	3	7-C	0.60	0.55	0.57	32.7	9.1	51.3	6.10	114.6	3.53	248.0	12.7	....	193.5	18.0	1.07
B	1	3	1 & 6	1.24	1.22	1.25	68.0	8.2	80.0	3.72	121.7	3.83	267.2	5.7	....	139.5	10.0	1.39
B	1	3	4 & 9	1.24	1.26	1.25	67.8	7.0	79.6	4.39	142.5	4.48	327.1	6.1	....	164.2	12.0	1.37
B	1	3	5 & 10	1.25	1.29	1.30	67.0	10.0	83.0	5.80	99.4	3.13	428.2	2.8	....	162.0	16.0	1.01
B	1	3	2 & 7	1.39	1.45	1.38	67.2	12.1	85.3	6.18	82.6	2.60	445.2	2.8	....	150.7	17.0	0.89
B	1	3	3 & 8	1.34	1.37	1.34	67.7	10.9	84.6	6.53	91.4	2.87	449.7	2.9	....	166.5	18.0	[illegible]
C	2	7	28	1.72	1.27	0.98	69.1	7.2	86.7	9.18	130.9	4.51	450.8	8.9	....	352	26.0	1.35
C	2	7	31	1.64	1.40	1.04	69.1	5.5	87.9	9.18	171.0	5.89	487.3	7.0	....	586	26.0	2.25
C	2	7	38	2.02	2.51	1.09	70.2	10.1	94.7	9.42	93.4	3.19	625.4	6.8	....	238	26.0	0.92
C	2	7	42	2.11	2.56	1.13	70.5	11.3	96.5	9.43	83.8	2.88	435.2	6.4	....	199	26.0	0.77
C	2	7	71	1.00	1.33	0.42	32.5	11.37	67.6	8.60	84.1	2.89	252.1	11.4	....	196	25.3	0.77
C	2	7	73	0.83	1.13	0.41	32.6	6.72	62.0	8.39	141.1	4.86	249.4	11.5	....	342	25.4	1.35
C	2	7	75	0.99	1.35	0.46	32.5	7.37	65.9	9.87	129.1	4.44	251.5	12.9	....	438	29.7	1.47
C	2	7	77	1.16	1.56	0.50	32.4	11.60	72.6	9.96	81.2	2.80	266.7	11.0	....	233	29.64	0.79
C	2	7	80	0.69	0.97	0.38	32.3	7.59	60.4	6.80	122.8	2.81	222.4	7.6	....	286	19.6	1.46
C	2	7	82	0.82	1.05	0.41	32.3	9.38	63.3	6.78	100.8	2.30	206.9	9.8	....	152	19.6	0.78
B	6	5	1-W	0.65	....	0.59	41.4	11.8	68.8	4.40	72.4	1.13	172	3.5	4.02	150	26.0	0.57
B	6	5	2-W	0.69	0.63	0.61	41.7	10.8	70.2	5.06	82.6	1.28	177	4.5	3.85	150	30.0	0.50
B	6	5	3-W	0.75	....	0.64	41.2	11.2	72.2	5.85	78.6	1.23	185	4.9	3.63	150	35.0	0.43
B	6	5	4-W	0.94	....	....	41.9	11.5	77.0	7.66	72.1	1.12	211	6.0	5.42	150	45.0	0.334
B	6	5	5-W	0.64	0.62	0.59	40.9	10.2	68.3	3.42	81.4	1.26	133	3.2	4.08	75	20.0	0.375
B	6	5	6-W	0.59	0.52	0.54	39.3	7.1	64.5	2.58	94.0	1.46	99	4.8	3.93	75	15.0	0.50
B	6	5	7-W	0.82	0.72	0.71	42.1	11.6	74.3	6.96	71.1	1.10	206	6.6	4.76	215	41.0	0.525
B	6	5	8-W	0.63	0.55	0.55	41.3	11.7	69.2	4.26	71.3	1.10	162	3.9	4.05	75	25.0	0.30
B	6	5	1-S	1.76	1.71	1.46	76.7	9.8	96.0	4.54	92.3	1.43	252	2.5	7.18	180	25.0	0.72
B	6	5	2-S	1.86	1.75	1.57	77.1	10.3	97.5	5.35	88.2	1.37	280	2.5	6.91	255	30.0	0.85
B	6	5	3-S	1.66	1.57	1.42	76.2	10.1	92.4	3.81	82.2	1.28	249	4.1	6.29	120	20.0	0.60
B	6	5	4-S	1.55	1.53	1.33	75.0	10.5	92.2	2.91	48.8	0.76	201	1.5	6.06	75	15.0	0.50
B	4	4	1	2.02	1.50	1.24	73.0	9.2	97.0	8.02	93.2	1.57	324	5.0	8.22	....	40.0	....
B	4	4	2	1.82	1.44	1.25	74.0	9.6	96.0	6.01	93.2	1.57	301	3.0	8.19	....	30.0	....
B	4	4	3	1.86	1.43	1.22	73.0	9.6	96.0	7.54	93.1	1.57	315	4.0	7.48	....	35.0	....
B	4	4	4	1.67	1.42	1.29	73.0	9.3	93.0	5.13	98.6	1.67	278	3.0	7.86	....	25.0	....
B	4	4	5	1.51	1.35	1.28	73.0	9.4	92.0	4.23	97.2	1.64	289	2.0	9.06	....	20.0	....
B	4	4	6	1.42	1.33	1.31	73.0	9.1	91.0	3.30	106.8	1.81	257	3.0	8.29	....	15.0	....
B	4	4	7	2.14	1.60	1.35	74.0	9.7	98.0	9.14	90.8	1.68	359	6.0	7.56	....	45.0	....
D	1	8	58	1.63	1.59	1.58	72.5	8.3	92.9	6.98	115.8	2.43	430	1.5	5.92	....	....	....
D	1	8	63	1.47	1.47	1.44	73.1	8.0	90.3	4.24	120.0	2.52	316	0.8	5.76	....	....	....
D	1	8	65	1.62	1.60	1.55	73.4	8.0	93.0	6.24	120.1	2.52	384	1.2	4.33	....	....	....
D	1	8	69	2.14	2.01	1.74	73.9	10.0	99.6	10.45	....	....	440	3.6	4.35	....	....	....

condensate. See Table 2. The curves for these condensers have a smaller range, indicating that it was possible to maintain a more nearly constant ratio of the cooling water to the steam condensed at all ratings and still maintain a satisfactory back pressure.

No elaborate tests have been run on either of the original installations at plant D. The single point D-1 on Fig. 13 is the result of three runs at practically the same operating conditions. The inlet water temperature was 73 deg. fahr., several degrees higher than the majority of the others outlined, but nevertheless shows a higher heat transfer and lower back pressure. Since this condenser has but 0.95 sq. ft. of surface per kilowatt installed, and resulted in very little undercooling, it appears to be a satisfactory installation. Circulating-pump input is not available from these tests.

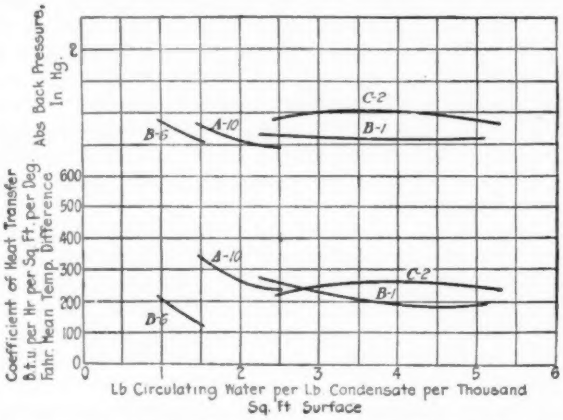

FIG. 14 COMPARATIVE PERFORMANCES UNDER WINTER CONDITIONS

(The letters and figures indicate the plant and condenser. The circulating-water temperatures are as follows: A-10 = 32 deg. fahr.; B-1 = 33 deg. fahr.; B-6 = 41 deg. fahr.; C-2 = 32 deg. fahr.)

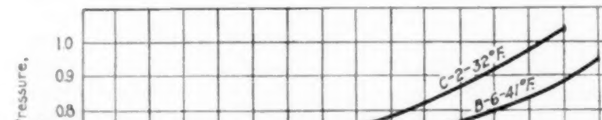

FIG. 14-A COMPARATIVE PERFORMANCES UNDER WINTER CONDITIONS

(Back pressures and heat-transfer coefficients based on per cent of rated capacity of turbo-generators.

Dotted lines indicate heat-transfer coefficients for C-2 and B-6 with the mean temperature difference computed by the logarithmic formula. Solid lines for C-2 and B-6 indicate heat transfers computed by the arithmetical mean temperature difference.

The letters and figures indicate the plant, condenser and inlet circulating-water temperatures.)

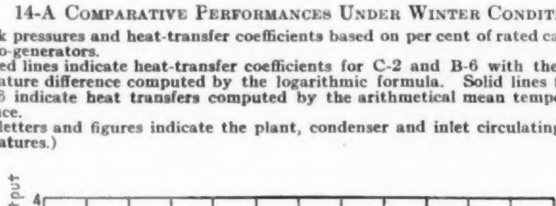

FIG. 15 POWER INPUT OF CIRCULATING-PUMP MOTORS

(Solid lines indicate summer conditions—circulating water at 66–70 deg. fahr. Dotted lines indicate winter conditions—circulating water at 32–34 deg. fahr.)

CONCLUSION

The condenser performances from the original installations to those of the present time, covering a period of seventeen years, show a marked improvement. This indicates that condensers of

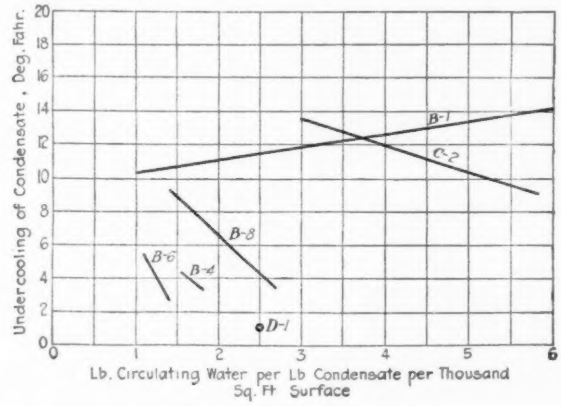

FIG. 16 UNDERCOOLING OF CONDENSATE

the single-pass type with a range of from 0.95 to 1.05 sq. ft. of surface per kilowatt of turbine capacity should be considered good practice. Their performance seems to outweigh the fact that a somewhat larger amount of water is necessary for this type of apparatus than for a two-pass condenser or a condenser having more tube surface.

Discussion at Session on Central-Station Power

THREE papers were presented at this session: namely, Operating Performance of Some Modern Surface Condensers, by Paul Bancel; Some Results of Condenser Operation, by E. B. Ricketts; and Steam-Condenser Practice and Performance, by F. J. Chatel. Mr. Ricketts' paper, which appeared in the Mid-November, 1926, issue, page 1312, gave the results of some fifty tests made at weekly intervals during 1925 and 1926 on four surface condensers of radically different design operating under the same water conditions and under the same supervision. The papers by Messrs. Bancel and Chatel appear on the pages immediately preceding. Written discussions on the three papers and a summary of the oral discussion follow.

DISCUSSION OF PAUL BANCEL'S PAPER ON OPERATING PERFORMANCE OF SOME MODERN SURFACE CONDENSERS

G. L. KOTHNY.[1] From the title of this paper one is led to believe that the author intended to publish detailed performance data of different types of surface condensers installed during the last few years, the analysis of which would show which type is the best to be used for certain existing conditions. Such data, if presented, would have been a valuable contribution to the Society.

When reading the paper, however, it is very disappointing to find that it deals only with one type of condenser, built by the firm with which the author is connected.

The synopsis of the paper brings out four cardinal points, the first one being that a modern condenser requires about half the cooling surface of one of the conventional type. Let us analyze this. If it is true, then single-pass surface condensers used as long as 15 years ago by the United States and the British Navy on destroyers and cruisers must have been far advanced in their times. I would like to refer to a paper by William Weir, now Lord Weir, read in 1912 before the Institution of Engineers and Shipbuilders in Scotland.

[1] Executive Engineer, C. H. Wheeler Mfg. Co., Philadelphia, Pa. Mem. A.S.M.E.

In this paper most of the principles which Mr. Bancel presents to the Society are already mentioned. Diagrams of tube-sheet layouts similar to the Ingersoll-Rand condenser are shown, as may be seen in Fig. 1. Fig. 2 shows a photograph of a Weir-Uniflux single-flow condenser in which the longitudinal control of the steam flow can be clearly seen.

Table 1 of Mr. Weir's paper, giving typical uniflux-condenser data and performance, installation No. 7 of the year 1912, records the following: Horsepower, 17,000 (12,700 kw.); steam consumption, 240,000 lb. per hour; cooling surface, 9000 sq. ft. of $^5/_8$-in. O. D. tubes 15 ft. long; condensation rate, 26.7 lb. per sq. ft.; vacuum obtained, 28.55 in. with 45 deg. fahr. inlet and 78 deg. fahr. discharge water temperature; hotwell temperature, 78 deg. fahr.; type of air pump, dual-twin beam. The temperature rise being 33 deg. fahr., the circulating-water quantity is calculated at 13,800 gal. per min. The number of $^5/_8$-in. tubes is 3670, giving a water velocity through the tubes of about 5.4 ft. per sec. and a friction head of 6 ft.

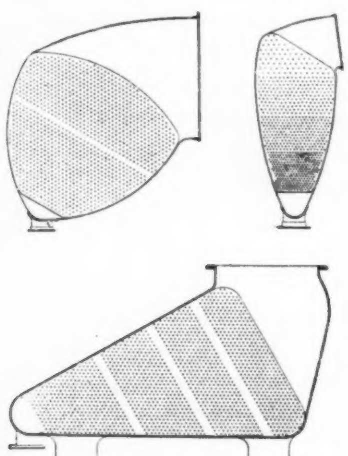

Fig. 1 Tube-Sheet Layouts from Lord Weir's Paper

These results compare very favorably with those published in Fig. 2 of Mr. Bancel's paper. For the same discharge water temperature, viz., 78 deg. fahr., the same cooling surface, 9000 sq. ft., for a load of 15,200 kw. or 158,000 lb. of steam per hour, with an inlet temperature of 64 deg. fahr. and a circulating-water quantity of 22,000 gal. per min., a vacuum of only 28.55 in. is obtained with the modern-type condenser at the Parr River 1925 installation.

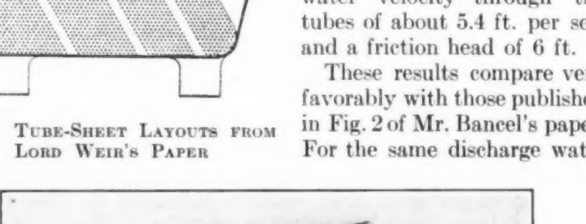

Fig. 2 Weir-Uniflux Single-Flow Condenser

The mean temperature difference in the Weir installation is 26 deg. fahr. and that in the Parr River installation is 19 deg. fahr. The heat transfer is 880 B.t.u. in the Ingersoll-Rand and 975 B.t.u. in the Weir condenser. The friction head in the Weir condenser is 6 ft. and that in the Ingersoll condenser is 14.5 ft., and the latter uses 1.6 times the amount of cooling water that the Weir condenser does.

It would seem that the Weir condenser of 1912, in spite of its handicap in not having an efficient air-removal apparatus nor multiple air pumps working at different pressures, nor having condensate traps to prevent flashing nor orifices for choking, gave better results at less operating expense than the modern 1925 Ingersoll-Rand condenser.

Condensers similar to the Weir-Uniflux type, with longitudinal steam distribution, have been in general use in marine installations, especially for cruisers and destroyers. Mr. Bancel deserves credit for the initiative of applying marine practice to stationary installations. There is no doubt that in some of these the application of marine practice will be beneficial. To suggest (by implication) that the two-pass-type condenser be sent to the British Museum is not sound advice, as the selection of a type of condenser is based upon the capitalized cost of the performance, operation, and maintenance. Heat-transfer efficiency ratio, cooling surface, etc. are only incidentals to this major consideration.

Mr. Bancel claims that there is no essential difference between operating and test performance. There should not be if the condenser is cleaned constantly to keep it in test condition. Fig. 1 in the paper indicates that the Ingersoll-Rand condenser at Parr was cleaned weekly. In another paper, presented by a condenser operator at this meeting, it is shown that the modern single-pass condenser required three sandblastings and fifteen washings, while a two-pass condenser was sandblasted and washed only once during the same period.

Point three of the synopsis is fully answered by the data given of the Weir condenser performance aforementioned, the 1912 Weir single-pass condenser showing better overall performance results than the 1925 Ingersoll-Rand condenser. This is not surprising, since Mr. Bancel chokes the air outlets by orifice plates and operates the steam jets at the different vacuums. Unless the tubes are packed tight by stuffing boxes into the support plate, the theory of having different absolute pressures in the four compartments will not work well. He carefully omitted to mention how the tubes are made tight in the support sheets.

It is also difficult to understand why different pressures in sections A, B, C, and D would not equalize on top of the condenser, even if the tubes are tight in the support sheets. After all, the total pressure in the condenser is the sum of the vapor tension and the partial air pressure. Since the temperature of the air-vapor mixture determines the vapor pressure and since this temperature is lower in section A, a more rapid flow of the mixtures would result, and there will be no stagnant air as shown in Fig. 13. External air coolers are not novel and were extensively used more than twenty years ago by different condenser manufacturers.

The friction curves given in Fig. 10 and based on Saph and Shoder's data (1903), while fairly accurate for the $^7/_8$-in. and $^3/_4$-in. tubes, give higher friction values for the 1-in. tubes than are actually obtained or calculated, based on later researches by Stanton and Pannell (London, 1914), by W. L. DeBaufre and Milton C. Stuart (Trans. A.S.M.E., 1919), and by Walker, Lewis, and McAdams (1923). A 6-ft. velocity in a 1-in. tube in a two-pass condenser would give the same friction as a 7.2-ft. velocity in a $^3/_4$-in. tube in a single-pass condenser, and not 8 ft. as shown by Mr. Bancel.

His statement that the $^3/_4$-in. tube would have an advantage corresponding to $\sqrt{8/6}$ over the 1-in. tube in heat transfer is incorrect, not only as far as the numerator is concerned, but also as far as its application is concerned. The change in water velocity affects the individual heat-transfer coefficient from metal to water film, but not the overall heat-transfer coefficient, of which Mr. Bancel speaks. This is explained in detail in another paper read by Messrs. McAdams, Sherwood, and Turner at this meeting.

P. E. Reynolds and S. W. Croll.[2] We have read Mr. Bancel's paper with a great deal of interest and if we allowed ourselves to follow his reasoning would be tempted to come to the conclusion that the single-pass condenser is the only efficient and desirable one. Furthermore it seems to us that the presentation of the excellence of the Ingersoll-Rand design takes precedence over the discussion of engineering features.

Mr. Bancel admits his original claim that a single-pass condenser having half the surface of a two-pass condenser could do the same work would be challenged, and we are inclined to think that this claim should still be challenged. Naturally if a single-pass condenser with half the surface does the same work as a two-pass condenser, the heat transfer of the former must be twice that of the latter and there are many data to show that this is not a fact. Numerous tests on two-pass condensers have shown heat transfers as high as 700 B.t.u. and even higher, using comparatively cold water, and we find no tests on single-pass condensers which show heat transfers very much higher than these figures.

[2] Respectively Vice-President and Mechanical Engineer, and President, Croll-Reynolds Co., Inc., New York, N. Y. Mem. A.S.M.E.

A test run this past summer on a 52,000-sq. ft. two-pass surface condenser at Waukegan, Ill., condensing 286,500 lb. of steam per hour and with inlet circulating water at 72 deg. fahr. showed the vacuum maintained was 28.85 in. of mercury. The rate of heat transfer on this particular condenser figures over 700 B.t.u., and incidentally the readings were taken using two mercury columns, two barometers, and checked by an absolute gage. The condensate was measured by a venturi meter. The measured air leakage was approximately 7 cu. ft. per min. The results obtained with the single-pass Ingersoll-Rand condenser during August, 1925, as given in Mr. Ricketts' paper, show that this condenser with 72-deg. fahr. inlet water and with a rate of approximately 280,000 lb. of steam per hour maintained an average vacuum of 28.23 in. Hg with a heat transfer rate of 496 B.t.u. Obviously these results do not show the superiority of the single-pass condenser claimed by Mr. Bancel.

Mr. Bancel brings out the fact, and we agree with him, that it is important to know how much steam is used by the air-removal apparatus. In the case of the 52,000-sq. ft. condenser mentioned above, the steam consumption of the steam-jet air-removal apparatus was 1100 lb. per hour. This, we think, compares very favorably with the 1800 lb. of steam per hour used with the 30,000-sq. ft. Ingersoll-Rand condenser at The New York Edison Company's Waterside Station.

We would also refer to tabulated operating data given in Mr. Ricketts' paper which give a comparison of operating results on a number of different types of condensers. We understand that the single-pass condenser mentioned in that paper marked "B" is one of the Ingersoll-Rand Company's condensers mentioned in Mr. Bancel's paper. A comparison of data obtained on this single-pass condenser with those on the two-pass condenser marked "D" would indicate that the results obtained by the two-pass condenser, which was installed in 1914, are equally as good if not better than those obtained with the Ingersoll-Rand modern single-pass condenser. The two-pass condenser marked "A" in Mr. Ricketts' paper does not seem to give as good results as the other condensers, but in determining engineering excellence of any particular design, comparison should be made with the best of the types representing this design rather than with the designs giving poor results.

Data published by Mr. William Weir in a paper read before the Institute of Engineers and Shipbuilders in Scotland in 1913 showed results of a number of tests on marine multi-pass pear-shaped condensers giving heat-transfer rates as high as 900 B.t.u. with vacuums of 28.5 in. Hg and better. We doubt that these results have ever been bettered by any of the modern single-pass condensers. Multi-passing in heat-transfer apparatus is not and never has been an indication of inefficiency as Mr. Bancel would lead us to believe.

As Mr. Bancel states, there is no reason why the heat transfer in a two-pass and a single-pass condenser should not be the same as far as the water side of the tube is concerned, provided the tube size and water velocity are identical. This being the case, the increased heat transfer claimed for the single-pass condenser must be obtained by an improved steam distribution and more efficient air removal, with a consequent increase in heat transfer on the steam side of the tube. Mr. Bancel states that this latter result is obtained in design by shell shape, tube spacing, external coolers, and longitudinal control. He uses the conical-shaped shell with graduated tube spacing, but there is no reason why this design cannot be employed with two-pass as well as single-pass condensers, and in fact this arrangement was used by Weir many years ago. It has also been used to a greater or less extent by many of the present-day designers of two-pass condensers. We agree with Mr. Bancel that it is a difficult matter to properly devaporize and shrink the steam-air mixture for efficient handling by the air-removal apparatus. However, we see no reason why a properly designed internal cooler should not be used. In any event the same design, whether internal or external, would apply equally as well to two-pass and single-pass condensers. The external cooler employed by Mr. Bancel has one advantage, however, in that the air-cooler surface is not included as condenser surface, thereby increasing to that extent the calculated B.t.u. transfer. The paper presented by Mr. Chatel relates that a number of two-pass condensers have from 15 to 25 per cent and over of their cooling surface in the air-cooler section. It would seem that improvement in air-cooler design would show a very marked increase in heat transfer for some of the present-day two-pass condensers.

Longitudinal control mentioned by Mr. Bancel is at best only an added complication peculiar to the single-pass design, and is automatically taken care of in the two-pass design. Also, the single-pass design with conical shell and graduated tube spacing unavoidably lends itself to the refrigeration of condensate with cold circulating water or light loads, and makes it necessary to use an external method of bypassing steam to the hotwell to overcome this difficulty.

As stated above, a design involving graduated tube spacing invites condensate refrigeration. There is, however, in the market at the present time a two-pass condenser using a modification of the graduated-tube-spacing idea which employs what might be called an adjustable central steam path or lane leading to the hotwell to overcome the refrigeration difficulty. Obviously refrigeration of the condensate cannot be controlled with varying circulating-water temperature and load without some such device. The adjustable central steam path mentioned above is regulated by baffles at the center of the condenser, these being controlled by levers from outside the shell which make it possible to regulate the amount of steam flowing to the bottom of the condenser in sufficient quantity to overcome the refrigeration.

In conclusion we would say it seems to us that Mr. Bancel's figures and arguments fail to prove that his single-pass condenser is the most efficient type, but rather point to the fact that the important considerations of shell shape, tube spacing, air cooling, and air removal should have been given more attention in the design of certain two-pass condensers.

Wm. Schwanhausser.[3] This paper exploits Ingersoll-Rand single-pass condensers as the latest and best of modern surface condensers. Mr. Bancel claims that the 30,000-sq. ft. Ingersoll-Rand condenser at the Waterside Station of the New York Edison Company is doing the same work as a 50,000-sq. ft. Wheeler C. & E. condenser in the same station with the same or less water. Data presented in Mr. Ricketts' paper support this claim, but it is noted that Mr. Bancel has chosen the poorest of all the condensers listed by Mr. Ricketts to prove the contention that a "modern" surface condenser requires about half as much surface as the type usually provided. If Mr. Bancel had compared the Ingersoll-Rand unit with the old 1914 Westinghouse unit in the same station according to performance data given in Mr. Ricketts' paper, the comparison would have favored the Westinghouse unit, although the latter has been in service ten years longer. The Westinghouse two-pass condenser gives higher average yearly vacuum, practically the same quantity of steam condensed per sq. ft. of cooling surface, condenses about 38 per cent more steam per gallon of circulating water, and requires less cleaning to accomplish these results.

Mr. Bancel claims that there is no essential difference between operating and test performances, and then cites one instance to prove this claim. From the information given in Mr. Ricketts' paper, it is known that the condenser selected as an example is cleaned more often than the other three condensers. Therefore the condenser in question is kept right up to test condition at all times, and so there is no reason why test and operating performances should differ. This is not, however, true in the majority of power stations, and the author's claim on this point cannot be conceded. No power station can stand the outages and costs incident to keeping condensers in test condition.

Mr. Bancel also claims that the results obtained are based on fundamental improvements in design which produce high efficiency in the utilization of surface with small expenditure of power. A comparison of units "B" and "D" in Mr. Ricketts' paper does not show that the improvements in design on surface condensers during the last twelve years have given any better results, nor that the present-day results have been obtained with any less power. Of course, condensers are smaller for the same kilowatt turbo-generator output now than a few years ago, but the greatest factor in this development has been the increase in turbine economy aided by the utilization of higher steam pressures and superheat temperatures, and the tendency toward interstage bleeding of turbines. There is

[3] Chief Engineer, Worthington Pump and Machinery Corporation, New York, N. Y. Mem. A.S.M.E.

no evidence that any improvements in condenser design as exemplified in the Ingersoll-Rand condenser have improved results. Certainly the comparison made by Mr. Bancel is not convincing to an engineer, and cannot be accepted as proof.

A careful study of the paper fails to disclose any real contribution to the engineering of condensers in general, nor any advance in design of condensers to improve power-plant operation or power costs. Such performance data as are given are in no way unique or new, as other condensers than the Ingersoll-Rand are doing as well or better, and this is so old a story that those concerned with these condensers have refrained from reporting results to the Society. It seems as if Mr. Bancel is evidently not familiar with these facts, and, in the opinion of many of those present, has approached dangerously close to what the Society forbids: advertising the apparatus of the company he represents.

Discussion of E. B. Ricketts' Paper on Some Results of Condenser Operation

G. L. Kothny.[1] Mr. Ricketts' paper is one of those useful papers which present actual operating data and thereby point out a lesson. It deals with the results obtained with four different types of condensers, results which, as he says, will provide condenser designers and operators with food for thought.

A brief analysis of the data published would indicate that the results obtained from the old, conservatively designed two-pass condenser "D" are better than those obtained from the single-pass condenser "B," which has been widely advertised as the "ace" of modern high-efficiency surface condensers, or than those of the single-pass condenser "C," which incorporates the novel idea of subdividing a large condenser into groups of tube or tube nests—which design has been abandoned as quickly as it was adopted.

Referring, for instance, to the data published for the month of November, condenser "D" produced the highest vacuum, viz., 29.14 in., condenser "B," 28.81 in., and condenser "C," 28.89 in. The ratio of circulating water to steam condensed is 75 for condenser "D," 80 for condenser "B," and 91.5 for condenser "C." The estimated condenser-tube friction loss is 6.6 ft. in condenser "D," 6 ft. in condenser "B," and 8.4 ft. in condenser "C." Assuming an efficiency of 80 per cent for the circulating pump, the power input for each 100,000 lb. of steam condensed is 31.6 b.hp. for condenser "D," 28.9 b.hp. for condenser "B," and 48.8 b.hp. for condenser "C."

The heat-transfer rate is 459 B.t.u. for condenser "D," 365 B.t.u. for condenser "B," and 390 B.t.u. for condenser "C."

Condenser "D" compared with condenser "B" produces 0.29 in. better vacuum with only 2.8 b.hp. larger power input to the circulating pump per 100,000 lb. of steam condensed. The increase in vacuum will decrease the water rate of a modern turbine about 2 per cent, or increase its power output about 200 kw. A net gain of 198 kw. will be obtained through the higher vacuum.

Similar conclusions can be drawn when considering the average performance of the four condensers over a year. Condenser "D" undoubtedly seems to be the most efficient one when considering not only the operating results but also the cost of maintenance.

During a year's operation it was washed and sandblasted only once. The single-pass condenser "B" had to be sandblasted three times and washed fifteen times, and single-pass condenser "C" had to be sandblasted three times and washed thirteen times, with no large variation in operating hours. Condensers "B" and "C" are only two years old, while condenser "D" is twelve years old. One cannot help asking how many times these condensers will have to be sandblasted and washed when they reach the age of condenser "D" in order to maintain the performance results which they are giving now. Also what the life of the tubes will be if they have to be sandblasted so frequently. Each sandblasting decreases the thickness of the tube walls.

Another point which should receive the attention of condenser operators is the number of tubes renewed per annum. Condenser "A" takes the lead with 474, condenser "C" follows with 147, condenser "D" is next with 42, while for condenser "B" so far no renewals have been reported. It would be interesting to hear from the author of this paper if these renewals have been due to water conditions or to the makes of tubes, the method of fastening them in the tube sheet, etc.

It is to be regretted that the author did not include in the published results the temperature of the condensate in the hotwell with no drains from the stage feedwater heater entering the latter.

These data are collateral to the performance results published, and therefore should not have been omitted. It is a well-known fact—and another paper dealing with condenser performance and presented at this meeting confirms it—that in the single-pass condenser the undercooling of the condensate averages higher than in two-pass condensers.

To recapitulate: The performances of the single-pass condensers as illustrated in the paper do not compare favorably with those of well-designed two-pass condensers, and their maintenance costs are high due to the necessity of frequent cleaning, which also reduces the period of availability for service.

Consideration should be given to these points by condenser operators when seeking condensers best suited to their requirements.

D. W. R. Morgan.[4] Mr. Ricketts' paper covering weekly tests extending over a period of one year on four radically different designs of condensers is extremely valuable from the standpoint of comparing the designs initiated over a number of years, for it has been difficult to obtain operating data on radically different designs performing under similar conditions.

For the month of September the table presented by Mr. Ricketts shows that units "A," "B," "C," and "D" condensed 5.8, 8.83, 9.0 and 9.81 lb. of steam per sq. ft., respectively. Analyzing the September performance further, using the water quantities indicated, and assuming a pump efficiency of 80 per cent applicable to the four units (which gives the pumps used in connection with the single-pass condenser the benefit of the doubt due to their operating at lower total head than the pumps used in connection with the two pass), indicates 288, 134, 105, and 205.5 hp., respectively, for condensers "A," "B," "C," and "D," all of which is set forth in Table 1.

TABLE 1 ANALYSIS OF CONDENSER DATA

Condenser	Sq. ft. surface	No. of passes	Lb. steam condensed	Lb. steam per sq. ft.	Gal. per min.	Water velocity, ft. per sec.	B.t.u. heat transfer	Horsepower June	Horsepower July	Horsepower Sept.
"A"	50,000	2	290,000	5.8	65,000	6.5	329			288
"B"	30,000	1	265,000	8.83	57,000	6.4	588		187[1]	134
"C"	30,000	1	270,000	9.0	50,000	5.9	476	137[2]		105
"D"	25,000	2	245,000	9.8	41,000	7.3	667		104.8[3]	205.5

[1] Circulating 55,000 gal. per min. [2] Circulating 65,000 gal. per min.
[3] Circulating 30,000 gal. per min.

Accepting this difference in horsepower without further investigation, one might argue that there is considerable saving in horsepower in favor of the single-pass condenser as shown by these tests. However, the condition is reversed during the month of July, which indicates 187 hp. for condenser "B" and 104.8 hp. for condenser "D."

Table 2 shows the pounds of steam condensed per square foot of surface, the horsepower for each month, and the average horsepower for the year. The average for condenser "B" is 144 hp.; condenser "C," 130.7 hp.; and condenser "D," 99.7 hp. A better study of the actual horsepower requirements could be made if Mr. Ricketts' paper indicated the number of hours' operation per month.

Considerable stress has been placed on the necessity of incorporating in the structure of single-pass condensers elements that will meter the steam quantity to a certain portion of the tube nest, while others advocate building in one shell what constitutes at least two or three separate condensers, each of which would operate at a different back pressure. If we expect to reach ultimate performance it can only be accomplished by directing our thoughts of design toward a structure in which equilibrium of steam distribution and absolute pressure is realized.

It is important that we exercise diligence in the design of a condenser, and it is of equal importance to correlate any excellence of design with the exhaust structure of the turbine. Obviously any attempt made to equalize the steam flow in the condenser is useless if the tube length bears no relation to the turbine exhaust.

[4] Chief Engineer, Condenser Department, Westinghouse Electric & Manufacturing Company, Philadelphia, Pa. Assoc-Mem. A.S.M.E.

TABLE 2 DATA ON HP. AND WEIGHT OF STEAM CONDENSED PER SQ. FT. OF SURFACE

Month	Gal. per min.	Gal. per min. per tube	Velocity	Hp.	Lb. steam condensed per hour	Lb. steam condensed per sq. ft.
CONDENSER "B"—30,000 Sq. Ft. Surface, 6006—7/8-in. Tubes, 21.9 Ft. Active Length						
August	57,000	9.5	6.4	134	280,000	9.34
Sept.	57,000	9.5	6.4	134	265,000	8.84
Oct.	64,000	10.66	7.16	178	290,000	9.67
Nov.	50,000	8.33	6.10	108	315,000	10.5
Dec.	52,000	8.67	5.85	104	330,000	11.0
Jan.	60,000	10.0	6.75	153	320,000	10.7
Feb.	58,000	9.68	6.51	139	325,000	10.8
March	60,000	10.00	6.75	153	327,000	10.9
April	64,000	10.66	7.14	178	325,000	10.8
May	57,000	9.50	6.40	133	325,000	10.8
June	56,000	9.34	6.30	128	295,000	9.83
July	65,000	10.83	7.30	187	275,000	9.17
Average Horsepower....................144						
CONDENSER "C"—30,000 Sq. Ft. Surface, 5694—7/8-in. Tubes, 23.3 Ft. Active Length						
Aug.	48,000	8.44	5.7	95	185,000	6.16
Sept.	50,000	8.78	5.91	105	270,000	9.00
Oct.	57,000	10.00	6.75	150	290,000	9.67
Nov.	57,000	10.00	6.75	150	310,000	10.3
Dec.	48,000	8.44	5.7	95	325,000	10.8
Jan.	46,000	8.08	5.45	84	320,000	10.7
Feb.	37,000	6.50	4.40	44	330,000	11.0
March	61,000	10.72	7.2	177	330,000	11.0
April	58,000	10.2	6.88	158	325,000	10.8
May	56,000	9.84	6.6	142	310,000	10.3
June	55,000	9.67	6.52	137	300,000	10.0
July	60,000	10.52	7.10	171	275,000	9.17
Average horsepower....................130.7						
CONDENSER "D"—25,000 Sq. Ft. Surface, 5612—1-in. Tubes, 17 Ft. 3 In. Active Length						
Aug.	33,000	11.75	5.88	114.5	205,000	8.2
Sept.	41,000	14.60	7.30	205.5	245,000	9.81
Oct.	32,000	11.40	5.70	105.0	220,000	8.18
Nov.	30,000	10.68	5.35	86.4	205,000	8.2
Dec.	29,000	10.33	5.15	76.6	205,000	8.2
Jan.	29,000	10.33	5.15	76.6	215,000	8.6
Feb.	27,000	9.62	4.80	62.3	245,000	9.8
March	31,000	11.04	5.50	93.8	240,000	9.6
April	30,000	10.68	5.35	86.7	200,000	8.0
May	28,000	9.97	5.00	70.8	190,000	7.6
June	33,000	11.75	5.88	114.5	220,000	8.8
July	32,000	11.40	5.70	104.8	185,000	7.4
Average horsepower....................99.7						

This is particularly true in the modern station where it is important that the head room be reduced to a minimum in order to minimize the station cost.

The writer is of the opinion that a large part of the tube inactivity is due to poor distribution of water to the tubes, and in this connection takes the liberty of referring to an article appearing in the November 9, 1926, issue of *Power*, entitled Condenser Study Shows Poor Water Distribution. As a matter of fact, the water boxes on this particular condenser are liberally designed and attempts have been made to obtain satisfactory distribution. The water boxes are unusually deep for the purpose of maintaining a low velocity and reducing the loss from the first to the second pass. We can only improve the hydraulic efficiency of this portion of the structure by a radical change in design, which will of necessity increase the cost of the structure and the space required. Here again the ultimate cannot be secured unless the circulating pumps and piping are located with the thought of improving the hydraulic efficiency.

The writer believes that the results that various people get from tests should be correlated and coördinated by such men as McAdams, Sherwood, and Turner, who have the time and who are sufficiently interested to get the meat out of them. He believes results obtained from time to time should be submitted to such men as these, for in that way we can arrive at a better understanding of subject than we have at the present time.

As a matter of interest, the writer calls attention to the tube-sheet layout of a 22,000-sq. ft. single-pass condenser installed in 1917 (Fig. 3), in which a low water velocity of 2.29 ft. was used and a B.t.u. heat transfer of 334 obtained, which corresponds to 540 B.t.u. at 6 ft.; also the tube-sheet layout of a 12,000-sq. ft. condenser (Fig. 4), employing a water velocity of 3.88 ft. per sec. and absorbing 403 B.t.u., which will compare with 500 B.t.u. at 6 ft. per sec. This condenser was shipped in 1924.

WM. SCHWANHAUSSER.[3] This paper presents a record of commercial operating conditions covering a period of one year on four radically different designs of surface condensers, all operated under the same water conditions and under the same supervision. No claims are made for any particular type, and the writer considers the paper a valuable engineering contribution. He does, however, feel that its value would be greatly increased if the following data were given:

1 Number of hours each unit operated each month so that truer average operating conditions may be determined.
2 Dates of installation of new tubes and number installed on each date. Condensers having greatest number installed may have been operating under handicap of reduced surface due to plugged tubes.

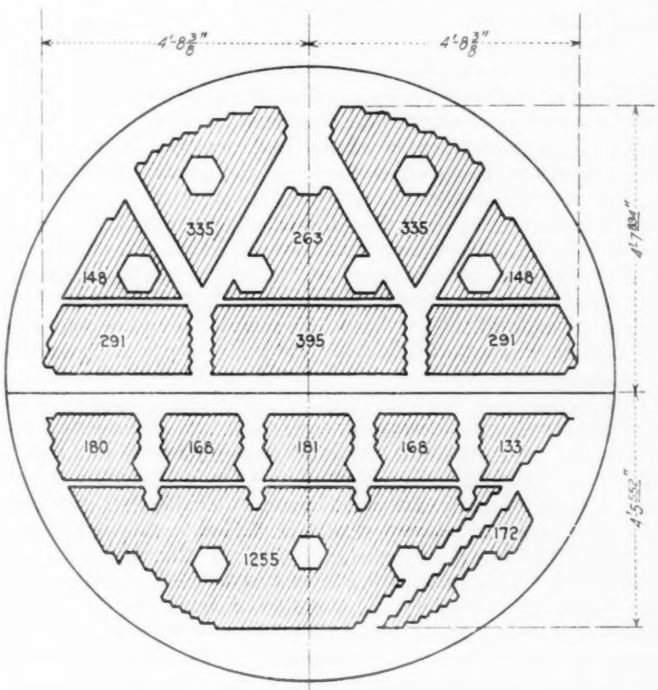

FIG. 3 TUBE-SHEET LAYOUT OF 22,000-SQ. FT. SINGLE-PASS CONDENSER, 1917

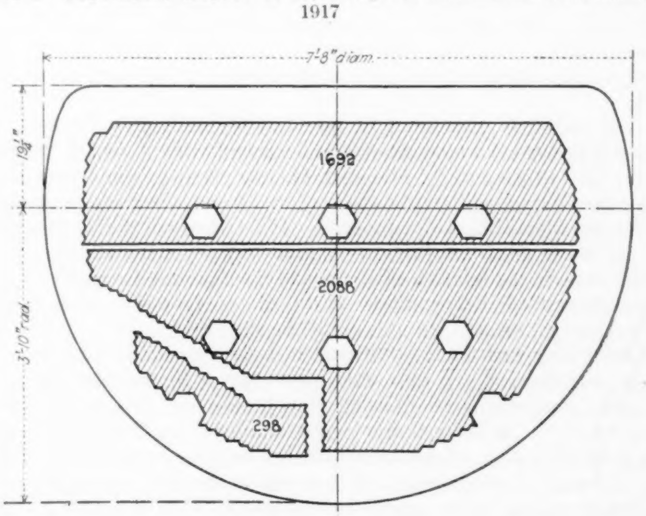

FIG. 4 TUBE-SHEET LAYOUT OF 12,000-SQ. FT. SINGLE-PASS CONDENSER, 1924

3 Pumping power required for circulating water on each unit.
4 Relative costs of installation of each unit, including condenser, pumps, piping, and tunnels.

Such information would be very useful in an effort to reach a conclusion as to the best type of condenser or the value of any one feature. In the final analysis, the decision must be based on dollars and cents: the cost of producing and maintaining a given vacuum as compared with value of the vacuum to the power plant as a whole. It is obvious that if one condensing plant were able to produce a higher vacuum than another by enough difference to add 5 per cent to the kilowatt output, then roughly it is worth \$5 per kw. more on a total plant cost of \$100 per kw. of capacity. Of two condensing plants substantially equal in vacuum produced, the differences in first costs, operating charges, and charges for outages must be evaluated to get a net difference which will favor one or the other.

Experience has failed to indicate any particular relation between such matters and the much-more-advertised high transfer rates. If the figures given by Mr. Ricketts prove anything, it is the fact that high vacuum is not the result of high rates of heat transfer, and of course on the above basis of valuation only a little better vacuum would be worth to the power station several times the cost of excess tube surface over a condenser with highest heat-transfer rate and least surface.

A few years ago much publicity was given to condenser "A," and a heat-transfer coefficient of 600 was reported under conditions of cold water and high vacuum. The average annual heat-transfer coefficient of this same condenser is reported as 258 in Mr. Ricketts' paper. This shows the fallacy in judging condensers by tests or by taking a high heat-transfer coefficient as indicative of efficient and economical condensation.

In a paper by Mr. Paul Bancel read at the Annual Meeting of the A.S.M.E.,[5] it is claimed that condenser "B" with 30,000 sq. ft. does the same work as condenser "A" which has 50,000 sq. ft., and does it with the same or less water. This comparison is not very convincing to the intelligent engineer, for it can be seen that the poorest unit reported in Mr. Ricketts' paper was chosen for comparison.

Comparing condensers "B" and "D," some interesting interpretations as to the single- and two-pass condensers are suggested. Condenser "B" is a 30,000-sq. ft. single-pass condenser with $^7/_8$-in. tubes, and condenser "D" is a 25,000-sq. ft. two-pass condenser with 1-in. tubes. Since the two condensers are of different size they must be compared on a basis of pounds of steam condensed. Condenser "D," although ten years older than "B" and with only one-eighth of the cleaning, gives a better average yearly vacuum. It condenses practically the same quantity of steam per square foot of cooling surface, and condenses about 38 per cent more steam per gallon of circulating water. Condenser friction in "D" is greater than in "B," but assuming the same external head on both units (and this favors condenser "B"), then condenser "D" only requires about 5 per cent more power for the circulating pumps than "B." Condenser "B" takes up more room than "D." The cost of installation of "D," including condenser, pumps, circulating piping, and tunnels, may be estimated at about 75 per cent of the cost of "B."

This, however, must not be taken to mean that two-pass condensers are superior to single-pass condensers, without qualifications.

H. G. Thielscher.[6] Mr. Ricketts has given us some valuable operating data on different designs of condensers which, as he states, gives considerable food for thought. It is to be regretted that some of the other vital information required to form more definite conclusions as to the relative efficiencies of the different designs has not been submitted, but analysis of the material presented leads to some interesting and surprising conclusions.

The writer has made additional comparisons in an attempt to gage the efficiency and commercial economy of the various designs. In these comparisons no allowance has been made for the fact that condenser "B" is favored due to not making any allowance for the separate air cooler, whose surface has not been included. Considering the ratio of condenser-shell free area to the cross-sectional area of the condenser tubes as 100 for condenser "D," we have 114 for "A," 280 for "B," and 212 for "C." Condensers "B" and "C," installed in 1924, exemplify the practice of large areas for steam flow to all the tubes, equal short paths to the air cooler, proper draining of the tubes, and uniform steam velocities, all of which factors should result in improved economy. As a result of this opening up of the steam space, we find that the index of pounds of steam condensed per hour per cubic foot of condenser volume runs as follows:

100 for condenser "D"
63 for condenser "A"
58 for condenser "B"
74 for condenser "C"

Thus, we should not expect condenser "D" to give the highest average heat transfer. If we look for the answer for this, we cannot find it in the matter of water velocities since they are as follows:

"A"—6.7 ft. per sec.
"B"—7.3 ft. per sec.
"C"—7.4 ft. per sec.
"D"—7.1 ft. per sec.

nor in the matter of pounds of steam condensed per square foot of heating surface, since the ratio, again considering "D" as 100, is:

68 for condenser "A"
112 for condenser "B"
112 for condenser "C"

nor in the matter of pounds of steam condensed per gallon of circulating water, since this ratio, again considering "D" as 100, is:

81 for condenser "A"
83 for condenser "B"
90 for condenser "C"

If we consider the circulating-water pump power, the ratio of power to pounds of steam condensed, again considering "D" as 100, is:

126 for condenser "A"
75 for condenser "B"
71 for condenser "C"

Summing up, these comparisons indicate that condenser "D" must be lowest in first cost, and slightly higher in operating cost than "B" and "C" and lower than "A." Condenser "D" gives a higher average vacuum than any of the others, and the gain over "B" and "C" should more than offset the difference in pumping costs.

Unless Mr. Ricketts can point out valid reasons which excuse the poorer performance of the later-day condensers, the writer must conclude that much money has been wasted in the new designs, and that condenser designers must start anew with renewed vigor to keep pace with the gains in economy which have been realized in other types of power equipment.

Discussion of F. J. Chatel's Paper on Steam-Condenser Practice and Performance

C. D. Zimmerman.[7] The valuable data given in this paper and the paper by E. B. Ricketts should furnish a step toward a more standardized and more efficient design of condenser, developed by analytical methods in place of the cut-and-try methods which have been necessary so far.

The object of the paper as stated is to furnish data by which the performance of several different condenser designs can be compared. These show that the recent designs have so improved in efficacy that improved results may be obtained with less surface than was used before. It is hoped that sufficient data will be available for future papers on this subject to enable readers to determine the relative value on a cost-of-operation basis of different condenser designs.

The usual method of comparison is to determine for each condenser considered total cost figures, which are plotted against the kilowatt output of the unit. The condenser having the lowest cost curve for the loads to be carried is then shown to be the most economical. Since the turbine water rate varies with the vacuum, the heat input to the turbine less the heat returned by the condenser is included in the total cost. The other factors of the total cost are the cost of the auxiliary power and the fixed charges chargeable to the condenser. In order to make these data applicable to any installation the vacuum which the condenser furnishes should be plotted against the steam or heat input to the condenser, and the pressure drop of the circulating water across the condenser should be given for different amounts of circulating water. Other factors always considered are the amount of air leakage and the relative cleanliness.

In order to predict approximately the performance of a condenser, the following equation may be of value:

$$t_v = t_i + w_s H \left(\frac{1}{2w_w} + \frac{1}{Sk} \right)$$

[5] See p. 219.

[6] Mechanical Engineer, McClellan & Junkersfeld, New York, N. Y. Assoc-Mem. A.S.M.E.

[7] Production Engineer, Steam Department, Cleveland, Ohio, Electric Illuminating Company. Mem. A.S.M.E.

This equation is derived as follows, taking:

w_s = steam condensed per hour
H = heat removed per pound of steam
w_w = pounds of circulating water per hour
t_v = temperature of steam in the condenser
t_i = temperature of the inlet circulating water
t_o = temperature of outlet circulating water
t_m = arithmetical mean temperature difference
k = heat-transfer rate.

$$t_m = \frac{2t_v - t_i - t_o}{2} \quad [1]$$

$$w_s H = w_w(t_o - t_i) \quad [2]$$

$$k = \frac{w_s H}{S t_m} \quad [3]$$

From [2]

$$t_o = \frac{w_s H}{w_w} + t_i \quad [4]$$

from [1] and [3],

$$k = \frac{2w_s H}{S(2t_v - t_i - t_o)} \quad [5]$$

from [4] and [5],

$$k = \frac{2w_s H}{S\left(2t_v - t_i - \dfrac{w_s H}{w_w} - t_i\right)} \quad [6]$$

$$k = \frac{2w_s H}{S\left(2t_v - 2t_i - \dfrac{w_s H}{w_w}\right)} \quad [7]$$

and from [7]

$$t_v = t_i + w_s H\left(\frac{1}{2w_w} + \frac{1}{Sk}\right) \quad [8]$$

That is, the temperature of the exhaust steam, and therefore the condenser vacuum, can be predicted provided the factors of steam condensed, amount of circulating water, and rate of heat transfer are known. Of course the difficulty lies in determining the heat-transfer rate. Outside of the cleanliness factor and the air leakage, the heat-transfer rate depends mainly upon the penetration of steam into the condenser and upon the velocity of the circulating water. The penetration depends upon the efficacy of the design, and increases with an increase in the amount of steam condensed and decreases with an increase in the mean temperature difference. Data are available on the variation in the heat-transfer rate with variations in the amount of steam condensed, in the mean temperature difference, and in the velocity of the circulating water. With these facts in mind one may estimate the probable vacuum, or change in vacuum, for changes in amounts of steam condensed, circulating water, and surface.

Condenser experiments leading to improved conditions have been planned at the Lake Shore Station of the Cleveland Electric Illuminating Company for some time, but in order to determine the effect of each change it was necessary to know the air leakage, since an unknown variation in this factor would make it impossible to determine the effect of the changed conditions on the condenser performance. Since most of the condensers were equipped with wet vacuum pumps without means of measuring the air leakage, it was found necessary to develop a means of making this measurement. This was done by using a bypass around the valve in the air line from the condenser to the air pump. To determine the air leakage it was necessary only to close the main valve and take readings on a flow nozzle in the bypass. This apparatus has been checked on a unit having a steam-jet air ejector whereby the air discharged at atmospheric pressure was measured, and has been found to be very accurate. The calculations, method of use, and condenser-performance studies will be published at another time.

It seems to the writer that there are two other factors in connection with condenser vacuum which have not had sufficient consideration: namely,

1 Steam leaving the last blades of the turbine is at a high velocity and in a highly turbulent condition. There is evidence that this steam does not meet the condenser surface evenly but "piles up" in certain sections. It is possible that improvements can be made in the connections from the turbine to the condenser which will lead to improved condenser performance. Experiments to determine the conditions in condenser connections at Lake Shore have been planned for some time, but have been postponed due to the press of more urgent work.

2 Steam leaving the last turbine blades enters an open space without streamlining, which is analogous to using an orifice in places where an efficient nozzle should be used. This sudden increase in the area of the passage causes violent eddies and turbulence as the steam changes from a high velocity on leaving the last blades to a lower velocity on entering the condenser shell. Due to this turbulence this change in state is accompanied by an appreciable increase in entropy and a consequent loss in the availability of the energy which, for the same vacuum at the top of the condenser, might be utilized in the turbine itself.

General Oral Discussion

D. W. R. Morgan,[4] speaking on Mr. Bancel's paper, said that as far as he knew, it took just as many B.t.u. today as it did ten years ago to raise a pound of water one degree. Our goal in condenser design should be to minimize the drop through the condenser and our thought should be directed along that line.

Mr. Bancel had made a very good point in suggesting that we use a method that might be recognized by every one in defining air-pump capacity. There was no reason why the Condenser Committee of the Society should not get together and define it. It should be defined by stating a definite quantity of air leakage, and the definition should take into consideration the temperature of the mixture at the air offtake and the amount of condensable vapor that might be carried over at that temperature.

Mr. Bancel referred to an N.E.L.A. publication as to the temperature in a two-pass condenser. Mr. Morgan believed, however, that there were sufficient data of more recent date that indicated clearly in the modern design the two-pass condenser would obtain approximately the same temperature rise in the first half as in the second.

G. L. Kothny,[1] referring to a remark made by Mr. Morgan in regard to the air-handling capacity of air pumps for different sizes of condenser installations, said that not only the actual capacity as far as free air was concerned but also the temperature of the air-vapor mixture should be considered, and that this had already been done by the United States Navy at Annapolis.

George A. Orrok[8] said that the three condenser papers were very interesting to him because they illustrated a point which he thought was frequently forgotten: namely, that no condenser in commercial service was ever really tested for heat transfer. All that the test meant was that what heat was there was transferred. In other words, it had never been tested up to the limit of the condenser surface.

When a heat-transfer test on a tube was made, all of the heat was supplied to the wall that could be transferred through the tube. When such a condenser test or record was made, one got just the transfer of the heat that was there. At 300 B.t.u. a transfer did not mean anything. The tubes were good for 1400 to 2000 B.t.u. if that amount of heat was there to be transferred. But tests were never made that way, and no operating man would ever buy a condenser with a small enough surface so that he could actually see what that surface could do.

Leo J. Levit,[9] referring to a statement made by Mr. Morgan, said that while it took as many B.t.u. today as ten years ago, at that time turbines were not bled as extensively as now. There was a difference between B.t.u. at high and low heat levels.

Abbott Allen[10] said that the operating man was interested in getting just as high a vacuum as he could. He wanted a condenser that would use as little circulating water as possible and was easy

[8] Consulting Engineer, New York N. Y. Mem. A.S.M.E.

[9] Power Plant Department, United Electric Light & Power Co., New York, N. Y. Jun. A.S.M.E.

[10] Assistant Mechanical Engineer, Stone & Webster, Inc., Boston, Mass. Mem. A.S.M.E.

to keep clean, and once every five years, perhaps, he thought about the cost of tube replacements.

The viewpoint of the man who designed condensers was or should be that he would like to get the best possible overall performance out of a minimum factory cost. That of the man who designed the power station was or should be that he would like to get the minimum overall cost of power at the station. This overall cost was made up of two components: namely, the operating cost and the fixed charges.

When one went into a further analysis of this latter viewpoint, which by and large should be the viewpoint of every one who was interested in condenser design and performance, he would find the matter was rather involved. In fact, nine out of ten, whether operating men or designing engineers, had found the problem so involved that they had thrown up their hands, and most of their decisions on the selection of type or the proportioning of surface and water quantities and number of passes had been made on the basis of pure guesswork, superstitions, preconceived ideas, and extraneous matter.

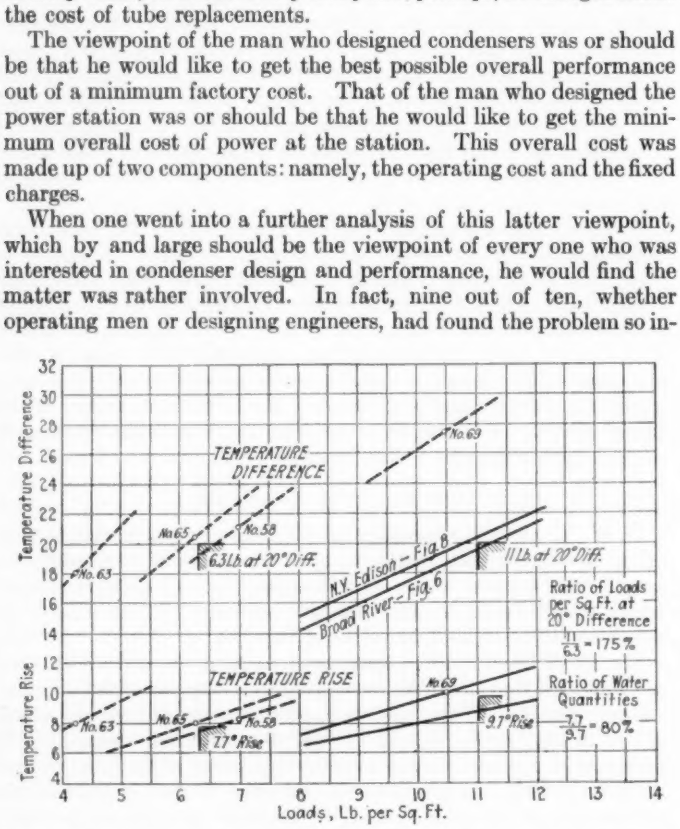

Fig. 5 Comparison of Ingersoll-Rand Single-Pass Condensers with Single-Pass Condenser at Detroit Edison from Mr. Chatel's Paper

Mr. Allen had found that it was possible to make an analysis which would enable one to weigh the relative merits of condensers of different types or of different proportions. It was necessary, however, before making that analysis to form an accurate idea of loading conditions on the generating unit during its active life—which ought to be taken as at least fifteeen or twenty years—to find out, corresponding to, say, 100 per cent, 70 per cent, and 40 per cent of the maximum throttle flow, for which the throttle was designed, what the number of hours of operation would be during each of the twelve months of the year.

The second thing as bearing on load conditions was that of accurately determining or determining by guesswork the date on which maximum demand would probably occur.

The next thing was to determine what the average circulating-water temperature would be during each month of the year. There must also be accurate curves showing the bleeding water rates of the turbine, corresponding to 100, 70, and 40 per cent of maximum throttle flow over a range of back pressures from a half-inch to, say, 3 inches; accurate curves of B.t.u. rejected to the condenser over a range of back pressures corresponding to, say, three different throttle flows; and an accurate knowledge corresponding to, say, these three different throttle flows as to what back pressures a given condenser would produce under day-in-and-day-out conditions; not test performance, but day-in-and-day-out performance, corresponding to different throttle flows. Further, one must be able to guess accurately the cost of tube replacements and the frequency with which they must be made.

There had been such an advance in condenser design that a salesman attempting to sell the equipment of eight years ago at the present time would almost have to give it away in order that the yearly costs would be equal to those of the condensers available today.

P. E. Reynolds[2] **agreed with Messrs. Bancel and Kothny that some** unit should be developed to determine the air-handling capacity of an air pump, that some unit should be designed which had a relation to the actual operation of the air pump. He was a member of the Test Code Committee, and would like to ask Mr. Kothny how the temperature of the air mixture was to be determined. He had had some little experience in the matter, and knew it was very difficult to measure the temperature of the air mixture, particularly when the absolute pressures were 1 in. or below. The density of the vapor at that stage or the specific volume was rather high, and it had been Mr. Reynolds' experience that it was very difficult to obtain a temperature which really represented the temperature of the mixture.

Paul Bancel said that a comparison of condensers "B" and "C," both 30,000-sq. ft. single-pass but of radically different designs, was of interest. In making such a comparison, the influence of small differences in vacuum on the true value of condensing machinery should be borne in mind. One-tenth of an inch of vacuum on the turbines under consideration was worth 2000 lb. of steam per hour, which capitalized to $35,000 of first cost on the basis of steam being worth 35 cents per 1000 lb. and approximately 6500 hours of operation with fixed charges at $12^1/_2$ per cent. With other figures, this might be lower or higher.

It was sufficiently close to set the figure at $30,000, thus giving one-tenth of an inch of vacuum as being worth a dollar per square foot of condenser. And from this it was apparent that it only took a few tenths of an inch of vacuum to be the equivalent of the entire cost of the condenser. Putting this another way, a condenser which was inferior by two- or three-tenths of an inch was a 100 per cent failure and would have to be given without cost to the user. On the other hand, a tenth of an inch of vacuum was a small difference from a practical operating point of view based on single or superficial observations. In this case, however, the averages of a whole month's or year's operation could be used for conclusive comparisons, as they represented an actual measure of differences in coal burned.

Taking the average performance as given by Mr. Ricketts for condensers "B" and "C," it would be seen that these were represented by coefficients of 432 and 392 for the two condensers over the whole year. On the basis of 300,000 lb. of steam, this difference represented approximately 0.1 in. of vacuum, which was shown above as the equivalent of a large part of the first cost of either condenser. To this also should be added any difference in jet steam consumption.

The records for May and July, that was, the month previous to sandblasting and the month after sandblasting, for both units, showed coefficients in the ratio of 121 and 122 per cent in favor of condenser "B." These coefficients translated into more nearly two-tenths of an inch difference in vacuum. The differences in actual vacuums reported in Table 1 checked this for July (0.18) when the reported loads were the same, but for May the load on "B" was higher than on "C," calling for correction to the reported vacuums. It was obvious that on the basis of the actual operating results, the difference in true value of the two condensers was a very large sum.

Mr. Bancel had made a comparison with the single-pass condensers at the Detroit Edison Co. The accompanying chart, Fig. 5, at the right showed the condenser performance of the two condensers of Fig. 6 and Fig. 8 in the author's paper. To his mind this was a very simple way of showing condenser performance. He had also plotted the four test points given in Mr. Chatel's paper for the latest single-pass condenser of the Detroit Edison, with just short lines pointing down toward zero for those four points. Those four points should be on separate lines, because all were on different water quantities.

Mr. Bancel had taken an average of tests 58 and 65 at 6.3 lb. per sq. ft. load and 20 deg., which was a typical temperature difference. On the Ingersoll-Rand there was an 11-lb. load to the square foot, taking an average of these two condensers, one of more recent design than the other and in a different plant. The temperature rise was 9.7 deg. average, and to the left it was about 7.7 deg. So that the ratio of the loads per square foot was 175 per cent, and the ratio of water quantities, 80 per cent. There was, he thought, a very marked difference in the actual efficiencies of different designs of condensers.

AUTHORS' CLOSURES

Mr. Ricketts in closing said that he thought Mr. Kothny had misunderstood the tube-renewal figures given in his paper. Their only significance was that if 2000 tubes were renewed during the year, it was evidence that during part of that time at least a considerable number of tubes had been plugged and were not in service. That fact had been put in to show that the condenser had not had the full amount of surface in service during the whole of the year. It had no significance as to repair costs, because his company's experience was that about once every six or seven years it became necessary to renew their condenser tubes. It would be noted that condenser "A" was about six years old during the period considered, and it was about time to get a new set of tubes.

Replying to Mr. Morgan, he stated the hours of operation were given in the table in the paper, and that in the curve sheets he would find the load on the condensers.

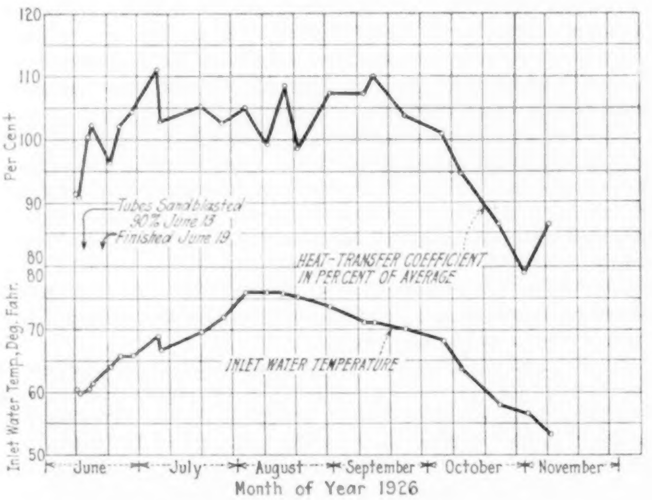

FIG. 6 RESULTS OF 24 TESTS OF INGERSOLL-RAND CONDENSER AT WATERSIDE

Mr. Chatel, in closing, said that the company he represented had gone to one-pass condensers in the latest installations; that did not necessarily mean that the one-pass condenser was superior to the two-pass condenser, everything considered. He believed, however, that the performance of these condensers, even though they might use more water than was necessary with the two-pass condenser, warranted their installation.

It had been shown that some condensers had a lower ratio of water quantity to the load. Some condensers had their surfaces reduced to such an extent that although the heat transfers were high, the safety factors were low and they required cleaning too frequently. The turbines had to be shut down oftener, and it was the policy of his company to install enough surface to result in safety factors which would not necessitate crippling the units too often.

Mr. Bancel in closing said that he did not think the matter of the vacuum pump, air temperature, etc., was so complicated as it might seem to some. It was a peculiar thing that one would see condenser performance quoted with elaborate calculations and conclusions, while the power for the vacuum pump was forgotten. This was proper enough ten or fifteen years ago when reciprocating vacuum pumps were used. The reciprocating vacuum pump took practically no power, the load being almost all friction. However, steam jets took considerably greater power, but should not. They should take very little, but actually in many plants throughout the country they were taking thousands of pounds more steam than they should.

What he had tried to suggest, Mr. Bancel said, was a very simple thing: that the steam quantity being used by the vacuum pump, be tied in with performance, be quoted along with performance, and be asked for when people were buying condensers. The only thing that had to be covered by the buyer or user was a statement of what the maximum air leakage should be corresponding to the amount of steam that was going to be used.

It was known that units could be operated nowadays on from 3 to 10 cu. ft. of air leakage. And it was very easy to find out for a particular case, because there were three or four air meters made that could be put right on the vacuum pumps and measure air leakage. The suggestion that he had to make was very simple—that the steam-jet power be tied into the picture.

Mr. Bancel also submitted a written closure in which he said that the discussion of his paper and also the remarks appearing as discussion of Mr. Ricketts' paper which referred to his condenser, could be grouped under the following classifications:

(1) Criticism of the author for exploitation of a manufacturer's product.

(2) Reference to the Weir condenser and tests reported by Weir to show that nothing new or novel had been accomplished, except possibly the change from multiple pass to single pass. Under this heading also came reference by Mr. Reynolds to a test of one of his condensers.

(3) Criticism of Mr. Bancel's claim to having accomplished at New York Edison with 30,000 sq. ft. the work previously accomplished with 50,000 sq. ft. by pointing out the fact that the tubes of the 30,000 sq. ft. condenser had been sandblasted three times.

(4) A repeated reference to condenser "D" in Mr. Ricketts' paper which, though five years older than the other two-pass condenser, showed superior results and should be compared with the author's condenser at New York Edison.

Taking these points in their order, Mr. Bancel wrote, the first might be readily disposed of by pointing out that he had been requested to prepare a paper by the Central Station Papers Committee, Power Division, and that this paper had been submitted to the Committee for the usual approval.

Regarding (2), it had been pointed out that the heart-shaped shell was nothing new and had been used many years ago by Weir. As a matter of record, the heart-shaped shell had been used before Weir's time by another manufacturer—almost forty years ago. It was also interesting to note that air preheating and bleed heating, both subjects of frequent discussion nowadays, had also been used thirty and forty years ago. From the test performances quoted from Weir's paper, also the test performances quoted by Mr. Reynolds, it might be possible to draw some interesting inferences. However, the purpose of his paper, Mr. Bancel wrote, had been to present operating results and not test results. While a gratifying amount of discussion and criticism had been advanced by various members, no operating data had so far been presented.

As to point (3), a claim that his 30,000-sq. ft. condenser had done the work of the 50,000-sq. ft. condenser of a conventional type, based on operation favored by frequent sandblastings of his condenser, would be misleading to say the least. His condenser had been sandblasted twice in the summer of 1925, around the start of Mr. Ricketts' cycle of performance, and the third time in June of 1926. Starting at this time a weekly test, independent of any results of operation, had been run and Mr. Ricketts had kindly given Mr. Bancel permission to present a summary of the results in Fig. 6 above. There would appear to be a slight temporary improvement due to sandblasting. The fact that it was temporary was proved further by the fact that the performance for the ensuing three months of July, August, and September showed no falling off in heat transfer. The reduction after September coincided with the circulating-water temperature, as would be expected. The same permanency of results for the previous year was indicated by Fig. 8 in the paper. Sandblasting might be said to have a negligible effect on operating performance obtained with the Ingersoll-Rand condenser. It would appear, however, that the effect on the other units was more marked.

Regarding (4), Mr. Bancel wrote that considerable criticism had arisen for comparing the Ingersoll-Rand condenser with one of the 50,000-sq. ft. condensers at Waterside No. 1, which also appeared as condenser "A" in Mr. Ricketts' paper, instead of comparing it with condenser "D" of Mr. Ricketts' paper. This criticism was summed up by the statement: "It can be seen that the poorest unit in Mr. Ricketts' paper was chosen for comparison;" also by the statement: "In determining engineering excellence of any

particular design, comparisons should be made of the best types representing this design rather than with a design giving poor results."

It should be clearly understood, Mr. Bancel wrote, that he had not been in a position to make any authentic comparisons, as he had not had the data now available. In the second paragraph of his paper the assertion had been made that the 30,000-sq. ft. Ingersoll-Rand condenser had done the work of the 50,000-sq. ft. conventional condensers, this claim being made on the basis of personal observations from time to time. In Waterside No. 1 there were four principal units, two 35,000-kw. machines with 50,000-sq. ft. condensers, and the two newer 35,000-kw. machines with 30,000-sq. ft. condensers. The turbines were similar in size and appearance and were usually operating at about the same output, the four units carrying a base load. Comparisons of performance of all four units were natural and largely a matter of comparing vacuums, which had been commonly done by visitors and by the station operating force. During the first six months to a year after installation Mr. Bancel had frequently been told by engineers that they had heard that the new condenser operated lower than the two 50,000-sq. ft. machines, the difference quoted being as high as $^5/_8$ in. The data now made public by Mr. Ricketts on one of these 50,000-sq. ft. units, which was presumably the better of the two, bore out Mr. Bancel's claims. Criticism advanced now for comparing the new condenser with units which previously had been widely used by engineers for comparison when it had been believed that they were superior, seemed to need no further comment.

The data now available on condenser "D," the 25,000-sq. ft. two-pass condenser installed in 1914, opened up another possi-

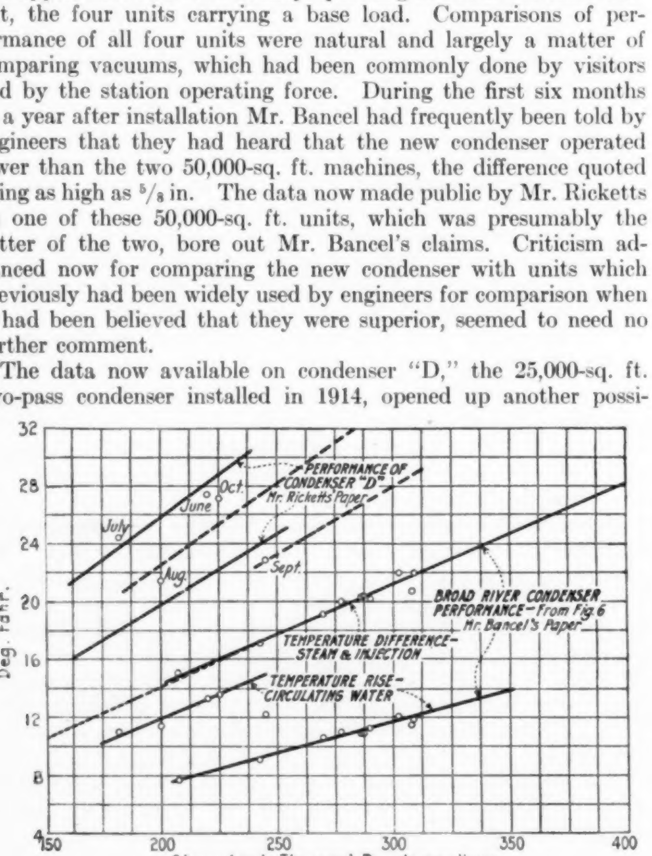

Fig. 7 Comparison of Performance of Ingersoll-Rand Broad River Condenser with That of Condenser "D" of Mr. Ricketts' Paper

bility for comparison. This unit was in Waterside No. 2 on a different-size turbine and in another house, so that personal comparison naturally had never been made. There were a great many other condensers in this house, and Mr. Ricketts had doubtlessly selected the one showing the very best results for presentation in his paper. Mr. Bancel believed that he was equally justified in making comparisons with any unit he might select, provided he presented authentic data, as, for example, for the 25,000-sq. ft. condenser at Parr, S. C., covered by Figs. 5 and 6 of his paper. Both condensers had 25,000 sq. ft. and the comparative results were shown by Fig. 7 above. It would be noted that the results for "D" were highly erratic. Taking the best month for condenser "D," September, 1925, when the tubes had been sandblasted and the heat transfer from Table 1 of Mr. Ricketts' paper jumped about 50 per cent, the chart showed loads of 245,000 lb. vs. 325,000 lb., or a ratio of 132 per cent in favor of the Broad River condenser. Again, taking the month of July, 1926, for condenser "D," the Ingersoll-Rand condenser carried 345,000 lb. as against 182,000 lb., or a ratio of 190 per cent. When doing this the temperature rise of the water was 13.7 deg. as against 11 deg. indicating 80 per cent of the water per pound of steam condensed. The average performance for the five months was represented by the dotted line; at 280,000 lb. the steam temperature with condenser "D" was 12 deg. hotter than with the Ingersoll-Rand condenser. This differential in temperature was fully $^1/_2$ in. vacuum and represented a loss capitalizing at about twice the cost of a condenser. Therefore, if condenser "D" of Mr. Ricketts' paper had been installed at Broad River, it would have been necessary to give it without cost and also endow the customer with a sum equal to its cost. Even taking September results for condenser "D," which were obviously far superior to the average, the vacuum at 245,000 lb. (Waterside load) was 5.6 deg. high or 0.3 in. low; at 300,000 lb. (Broad River load) the vacuum temperature was 6.8 deg. high or 0.4 in. low; these differences when capitalized were more than the equivalent of the entire cost of the condenser.

A few further remarks which did not come within the four classifications mentioned above, might be answered briefly. Mr. Kothny criticized Mr. Bancel's curves for tube friction, also the use of the square-root law for the change of heat-transfer coefficient. The friction curves based on Saph and Schoder had been checked some years ago in the Ingersoll-Rand laboratory and found to be safe. Mr. Bancel wrote that he was glad to receive criticism as to their consistency as between 1-in. tubes and the smaller sizes, and this would be rechecked. As regarded the use of the square-root law for heat-transfer coefficient, he had considered this as a widely accepted and widely used relationship.

Mr. Kothny presented a photograph of a Weir condenser with support sheets extending up into the steam space. Mr. Bancel wrote, however, that his remarks about longitudinal control had referred to extension of the support sheets down to the bottom of the condenser. Mr. Kothny appeared concerned about leakage of steam through the holes in the support sheets. As to this, one of Mr. Bancel's earlier inventions on file with his legal department showed an arrangement for sealing the holes with water, but this was now known to be unnecessary.

Mr. Reynolds suggested that the important considerations of shell shape, tube spacing, air cooling and air removal should have been given more consideration in design of certain two-pass condensers. It had been his aim, in the last part of his paper, Mr. Bancel wrote, to point out that these features were fundamentally important with any condenser, no matter how many passes it had. His company had built a number of multiple-pass condensers and employed the same features of design. They were, however, of particular interest and importance with single-pass condensers because single-passing put a premium on good design. Mr. Morgan's point that condensate temperature was of just as much importance today as ever had been answered by Mr. Levit. Readers were also referred to Trans. A.S.M.E., vol. 45, p. 733.

Mr. Alden pointed out the necessity of careful investigation when selecting the size and type of a condenser, and made the statement that the present-day condenser was far in advance of the design of eight years ago. It was Mr. Bancel's conclusion, based on his calculations and also careful studies made by others, that the single-pass condenser was indicated for the majority of conditions in the majority of plants. It was believed that most of the new turbines now building for leading stations, were being fitted with single-pass condensers.

Utilization of Short-Length Lumber

THE National Committee on Wood Utilization of the United States Department of Commerce has recently published a very important bulletin entitled The Marketing of Short-Length Lumber. This bulletin, containing 28 pages, after defining what short-length lumber is, emphasizes the importance of its utilization by the statement that the output of softwood lumber in the United States could have been increased at least one-fifth in 1925 without felling a single additional tree if lengths of less than eight feet had been in wider demand.

After a chapter devoted to the important factor which short-length lumber can be in building economy, specific opportunities for utilizing short lengths in the practical construction of houses, barns, etc., are described in much detail. The Wood Industries Division of the A.S.M.E. urges the study of this bulletin by all those interested in timber conservation and building economy. Copies may be obtained at ten cents each from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Tensile Testing of Textiles

Development of Use of Tensile Testing in Textile Industry—Present Status—Need of Reliable Testing of This Nature—Practical Use for Both Manufacturer and Buyer of Yarns, Threads, and Woven Fabrics—Probable Trend of Future Developments

By W. F. EDWARDS,[1] NEW YORK, N. Y.

THE practice of guessing the tensile strength of yarns, threads or fabrics by tactile and muscular senses has doubtless come down to the present time from a beginning lost in a remote past. The method is still in use on light yarns or fabrics, and, in the hands of a person handling such yarns or fabrics every day, year after year, may give a very good indication of relative strengths, but does not furnish reliable numerical results.

Early Types of Testing Instruments

Numerical estimates were first attempted by the application of an ordinary spring scale with a hook attached, to which a yarn or thread could be tied and then pulled by the hand, holding the yarn or thread at a fixed distance from the hook until it broke. The operator read the scale continuously in order to have an approximately accurate reading at the time of breaking. Improvement was made by adding a device to prevent the recoil of the spring at the break until the reading had been made and recorded.

The reliability of the spring-balance method was questioned and the easily abused spring was replaced by a weight which introduced the inclination-balance or "deadweight" type of machine. A pointer moved along a graduated quadrant which gave the breaking strength directly. The deadweight instrument is provided with a device to prevent the sudden return of the weight after the break and to hold it at the breaking point until the reading has been taken and recorded. A form of this primitive instrument is shown in Fig. 1. It is obvious that, in both the spring-balance and this type of inclination-balance machine, the rate of stretch was likely to be quite variable, since in both cases the power was a voluntary muscle controlled by the operator.

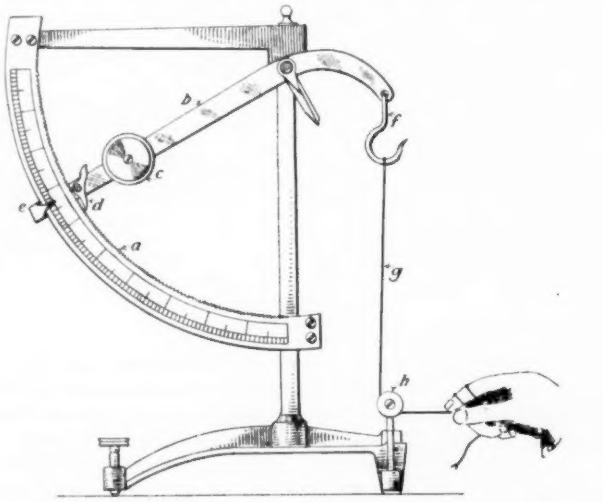

Fig. 1 Early Type of Deadweight Testing Instrument

Present-Day Instrument

The inclination-balance type of testing instrument or machine of the present day is in principle the same as that shown in Fig. 1. Some are still hand driven, but where results are to be compared to any reasonable degree of accuracy, the machines should be power driven and furnished with devices to insure an approximately uniform rate of stretch from the beginning to the end of the pull.

Two ways of producing a uniform rate of stretch are in common use. The pump-plunger weight motive power is most common in single-strand testers, and a screw driven by a constant-speed electric motor or constant-speed belt is used for heavier machines. Fig. 2 is an illustration of a common pump-plunger type of single-strand tester, and Fig. 3 is an electric-motor-driven type with automatic recording chart attached.

Tensile tests on yarns, threads, and fabrics by constant-stretch machines may be considered as a development within the twentieth century. The instruments or machines for making the tests have improved until they are quite competent for the usual tests, and are now provided with means for showing the stretch as well as the strength. Most of the heavier machines are now provided with means for automatically recording curves of the stress-strain relation for all loads to the breaking point.

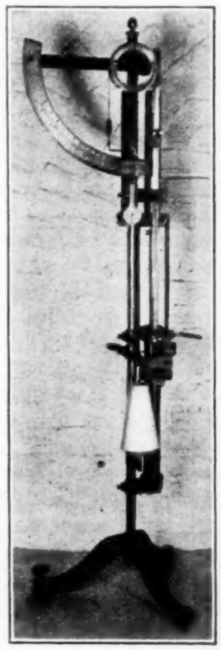

Fig. 2 Common Pump-Plunger Type of Tester

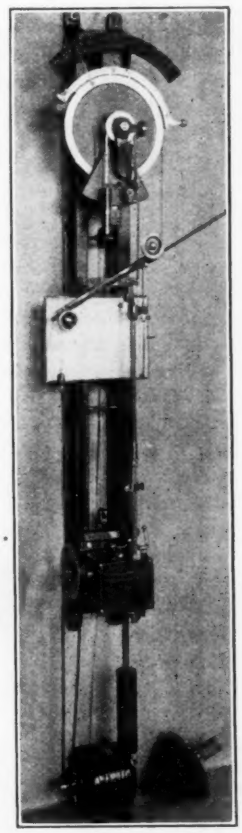

Fig. 3 Electric-Motor-Driven Type of Tester with Automatic Recording Chart

The tests themselves are often very inadequate and made to show more than is warranted by reasonable interpretation of the results. European countries, for example, have used a tensile test on raw silk for several decades, but formerly limited the test to ten breaks at more or less random places on the same yarn, or to one break on each of ten yarns taken from different sample skeins. (One hundred breaks are recommended as a minimum in the United States.) An arithmetical average of the ten breaking strengths and of the ten elongations establishes the strength (tenacity) and stretch (elongation) of the raw silk under test. Every break is recorded, however, to show the regularity (evenness) in cross-section of the yarn as an indication of uniformity in covering power. The strength and elongation are what are determined and recorded, but the indication of variation in the diameter of the yarn is often, if not always, considered of quite as great value as the average strength.

The tensile tests applied to raw silk are typical of tensile tests applied to all yarns and woven fabrics in that they emphasize three main points: a constant rate of stretching throughout the test, the stretch to point of rupture, and the breaking strength.

The inadequacy of ten breaks ultimately led to making more breaks, and to a machine for automatically recording the breaks—a type of machine known to all of us, which automatically makes and records the breaking strength of a considerable number of consecutive breaks at regular space intervals on from one to ten yarns, but

[1] Director of Laboratories, U. S. Testing Co., Inc., New York, N. Y.

Contributed by the Textile Division and presented at the Annual Meeting, New York, December 6 to 9, 1926, of The American Society of Mechanical Engineers.

which gives no indication of the stretch and does not give average strength, and is therefore an evenness tester rather than a tensile tester.

Recording Instruments

Machines designed to show the breaking strength and stretch at rupture and which automatically record the stress-strain relation from the beginning to the end of the test have come into use within the last decade, especially in the case of machines having a breaking capacity of 50 lb. or more. The record appears in the form of a

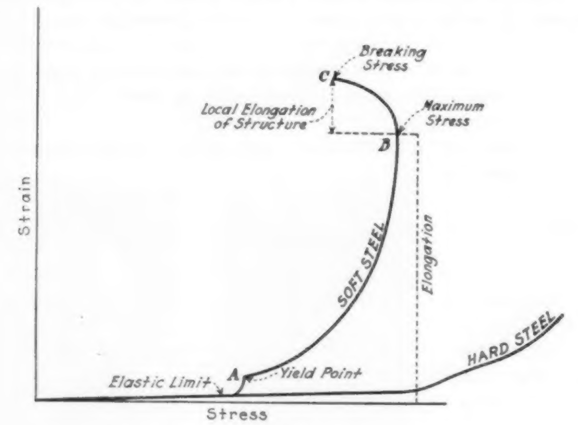

FIG. 4

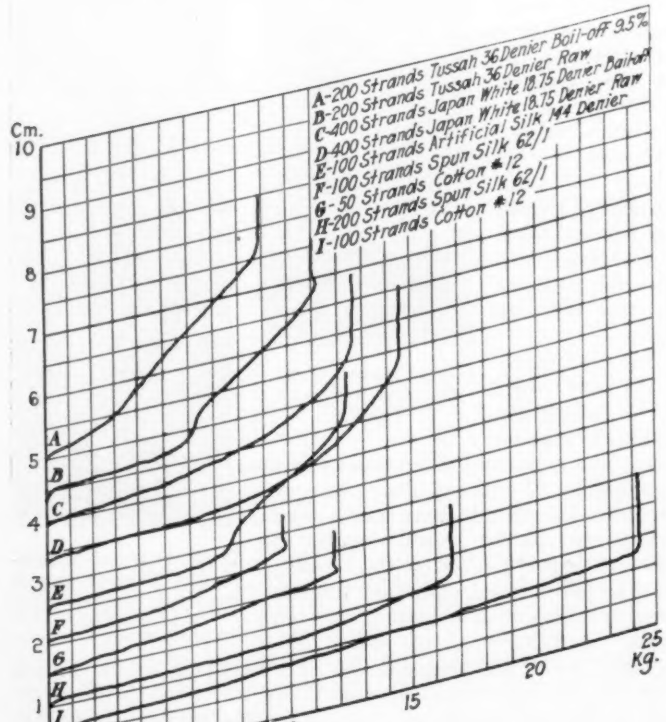

FIG. 5

curve traced by a pen or produced by a series of dots made at regular intervals by electric sparks.

A comparison of the characters of these yarn curves with curves from steel wires can be made by comparing the curves of Figs. 4 and 5. The curves for steel wire show three important points: the yield point, the breaking strength, and the stretch at point of maximum load; while the curves of Fig. 5 on yarns show only the latter two.

The curves for the yarns show certain characteristics that are worthy of further attention. The curve H for spun silk has the characteristic shape of the spun yarns of which curves I and G for cotton yarns may be taken as typical. The spun yarns usually show small stretch, which is approximately proportional to the stretching load, as is the case of the steel wire up to the yield-point load (shown by Fig. 4).

The humps in curves B and E are not yield points in the ordinary sense but are change points in the rate of plastic flow, which rate is different on opposite sides of the hump. The hump on curve B is due to silk gum and does not occur if the gum is removed before testing, as shown by curve A which is made from the same skein of Tussah raw silk that was used for B, the only difference being that the gum, amounting to 9.5 per cent, was removed by weak soap solution in the usual way before the test was made. Curve E

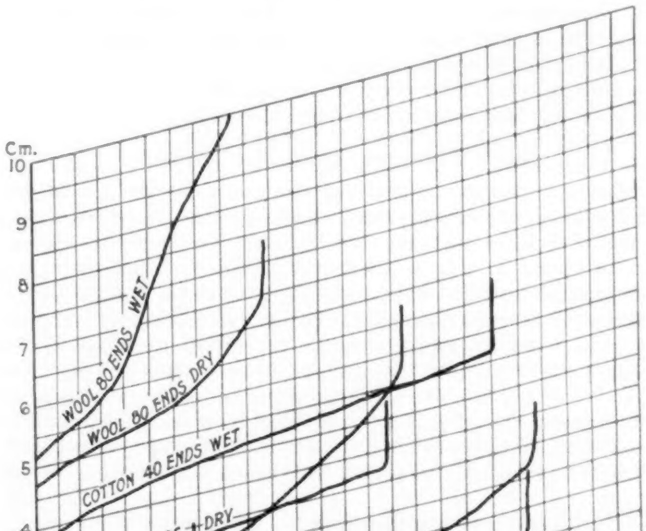

FIG. 6

was characteristic of most rayon yarns three years ago, but it has almost disappeared in most of the present-day products, the change in rate of plastic flow being far less abrupt now. Curves D and C are for Japan raw silk before and after removal of sericin. The per cent of the gum removed is more than twice as great as for the Tussah silk of curve B, but it shows no sign of hump in the curve D.

Effect of Atmosphere

The breaking strength and stretch to rupture are very much affected by the moisture content at the time of the test, and usually differently for yarns and fabrics made of different textile fibers. The strength may vary as much as 60 per cent between tests made on the same yarn or fabrics when dry and when wet. Figs. 6 and 7 will give a rough idea of these variations. These curves show stress-strain relations for yarns dry (in equilibrium with standard atmosphere) and wet (dipped in water at room temperature for a few seconds and tested while still wet). Fig. 6 shows curves for the same number of ends wet and dry, and Fig. 7 shows curves with the number of ends wet and dry taken so as to give approximately the same ultimate strength. Note that there is no hump in the wet-rayon curve.

The comparison of tests made on the same yarn or fabric in different laboratories requires that the test samples have approximately the same moisture contents at the time of the test. This can be accomplished best by exposing the samples for a sufficient length of time in a standard atmosphere.

The production and maintenance of this standard atmosphere, at a reasonable cost in a room large enough to be used as a testing laboratory, against all changes of temperature and moisture content

in the air outside, is the great field for improvement presenting itself to all interested in reliable and comparable tensile tests on textiles. Three ways have been proposed as substitutes for the testing room with constant standard atmosphere. One is that of making the test in a comparatively small chamber in which both the test samples and the testing instrument or machine are placed. The operator manipulates the samples and machine by suitable devices from the outside. This method has been worked out so as to be fairly competent for experimental purposes, but is not suited to laboratories making a large number of routine tests, both on account of inconvenience and very large installation cost.

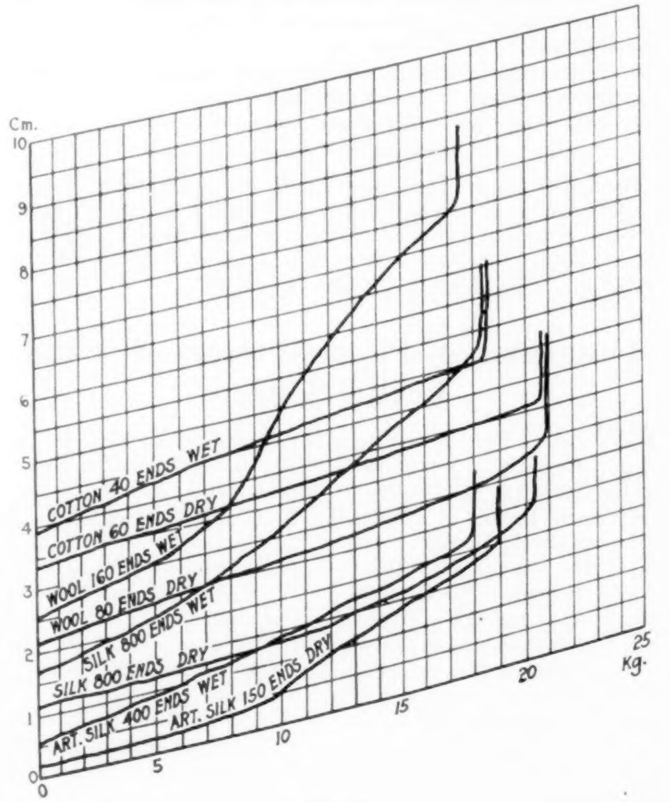

FIG. 7

A second is that of making the tests in any atmosphere and then drying the sample to determine its actual moisture content at the time of the test, from which, by an established correction formula, the strength of the sample in equilibrium with standard atmosphere can be computed.

A correction formula for cotton fabrics has been worked out and has proved to be fairly reliable where tried out carefully. The correction factor depends on the weight per square yard, W, and the per cent moisture regain, M, at the time of test, and the standard regain of 6.5 per cent.

$$\text{Correction factor} = \frac{100 + 6.5(^3/_8W)}{100 + M(^3/_8W)}$$

The strength found by test, multiplied by this factor, gives approximately the strength for a moisture content which corresponds to the standard regain of 6.5 per cent. More data on the use of this correction formula will be necessary before enough confidence in it will be established to bring out the necessary tables of corrections to convert found strength to standard atmosphere strength. Accumulation of data from this method is worthy of careful consideration.

A third is that of testing all yarns and fabrics in a wet state. This method is quite easy to carry out, but so far there are not enough data to show its practicality.

How necessary and how complicated the maintenance of standard atmosphere is in some places will be understood by a study of the temperature and relative-humidity curves shown in Fig. 8, which the charted records show for a Southern cotton mill for the month of August, 1925. A study of these curves in connection with a vapor-pressure curve, such as that of Fig. 9, will show that the moisture content of the air was fairly constant throughout the day for most of the three-month period, but that the relative humidity changed from between 20 and 30 to between 80 and 90 per cent every 24 hr., except in a few instances which are probably accounted for by showers.

The same yarn or fabric tested under standard atmosphere conditions may show a variation as great as 20 per cent between tests with 6-in. and 24-in. rates of stretch per minute, depending somewhat on the stretchiness of the yarn or fabric—the more stretchy the greater the variation as a rule.

Standardizing the rate of stretch for the tests is probably the best means of overcoming this difficulty. A single standard rate may not be found desirable. The serigraph test for raw silk is standardized to have a 6-in.-per-min. rate of stretch, higher rates having been found much less consistent and reliable. In comparing the effect of rates of stretch, the same length of specimen should be used.

CONSTANT-RATE-OF-LOADING MACHINE

Constant-rate-of-loading machines have been proposed from time to time as a means of overcoming the difficulties found in comparing te nsile tests, on account of variability in stretchiness. By this means samples of fabrics having different stretch but about the same ultimate strength could be brought to the break in the same time through the constant-rate loading. Some very ingenious devices have been brought out in Europe (some with autographic recording charts) in which a constant flow of water or fine shot constitutes the constant rate of loading. These machines have been used successfully for experimental purposes, but the author knows of no adequate data from their use to show that they have any practical superiority over the constant-rate-of-stretch machines.

A very ingenious constant-rate-of-loading machine has been brought out in this country which is motor driven and does not depend on a flow of water or shot, yet gives a constant rate of loading, whatever the chosen rate or whatever the length, strength, or stretchiness of the sample. More work should be done with this machine to establish its superiority over the constant-stretch, deadweight type of machine for practical purposes. If the superiority can be well established, simplification of the machine should be studied so as to make possible a machine for practical testing as well as experimental laboratories.

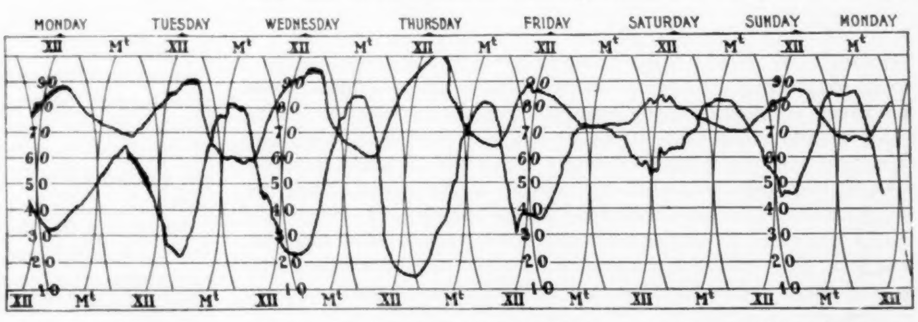

FIG. 8 TEMPERATURE AND RELATIVE-HUMIDITY CURVES TAKEN IN A SOUTHERN MILL DURING A WEEK IN AUGUST, 1925

Ballistic types of tensile testing machines for yarns and fabrics have been proposed, designed, and used in the hope that more accurate results might be obtained than those from tests on the constant-stretch machines, but the author knows of no adequate data on results from practical use to warrant further mention here. This type of test has its appeal to those interested in energy considerations.

INTERPRETATION OF RESULTS

Tensile tests, in order to be safely comparable, must be made on the same type of machine very carefully in the same way in every particular. Placing and clamping the sample in the grips (jaws) carelessly may make a quite considerable difference in the result.

The twist of yarns should be carefully preserved in the gripping operation. Strips of fabric should be clamped so as to avoid, as far as possible, making a tearing test by breaking first on one side and tearing across the strip, etc.

The art of interpreting the results from tensile tests on yarns, threads, or fabrics, with reference to their various uses, is to a great extent still in its infancy, but there seems to be a rapidly growing understanding that an intelligent tryout in practice is essential to safe interpretation.

The interpretation depends to a very great extent on the use to be made of the textile product tested. A square-woven tire fabric or

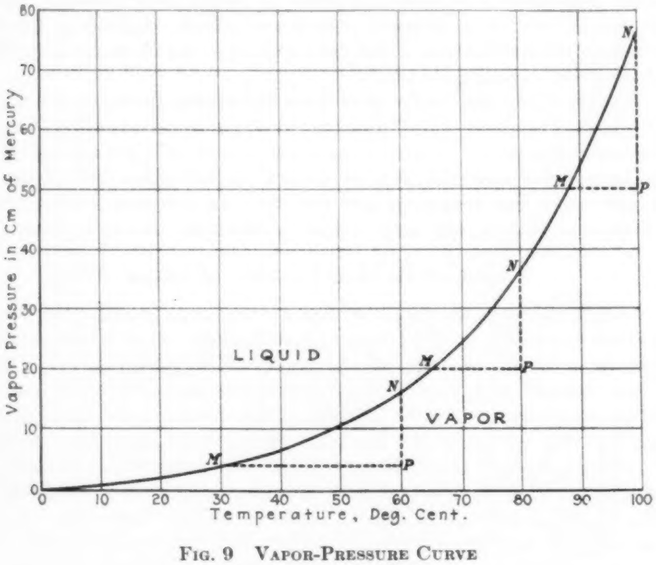

Fig. 9 Vapor-Pressure Curve
Water Vapor at Saturation

Temperature, deg. cent.	Vapor pressure, cm. mercury
0	0.46
5	0.65
10	0.91
15	1.27
20	1.74
30	3.15
40	5.49
50	9.20
60	14.89
70	23.33
80	35.49
90	52.55
100	76.00
150	358.00
200	1168.90

airplane cloth should have the same strength and stretch in both warp and filling directions, and in heavy fabrics crimp should be given consideration in connection with stretch. A belting duck should show high strength and low stretch in the warp direction, but in the filling direction high strength might be undesirable. An osnaburg used for making a waterproof fabric for waterproofing cement structures such as swimming pools, should not be compared with osnaburgs suitable for cement sacks. Strength might be given undue importance in the first case, but in the second case it could not be less than a determined value found necessary in practice.

Strength may be emphasized too much in a specification of a fabric, for example, such as those used for making the uniforms of policemen where wearing quality is of first consideration, a better wearing material being often available at a lower cost if the strength specification were not so high.

A tire cord should show the desired strength and should show a high stretch as compared with that of the singles from which it is made, the stretch of the cord being usually from four to six times that of the single yarn.

These examples will give a hint as to interpretation in practice, but should be studied carefully in use and not accepted as rule-of-thumb.

Future Investigation

Future investigations for the purpose of general improvement in tensile testing of textiles will probably center about one or more of the following points of departure:

1 The development of constant-temperature and relative-humidity testing rooms.

2 A more comprehensive study of the comparative merits of the large number of different grips already in use, which would probably bring out in course of time something superior to anything yet designed.

3 Studies to determine the most desirable constant rates of stretch or loading with special reference to the possible establishment of a single constant rate that will serve for tests on a considerable variety of yarns and fabrics.

4 Studies to determine the relative merits of averages of single-strand tests and skein or lea tests and yarn-strip tests.

5 Size and face of jaws best suited to strip and grab tests on woven fabric.

6 Interpretation of results of the tensile tests for different materials used for widely different purposes.

7 Others less definite of statement.

8 Practical uses not thought of today.

Meanwhile the deadweight pendulum type of machine designed to give constant stretch and autographic records has reached a state of perfection, and methods of using it have become sufficiently standardized to warrant a very wide application of tensile tests to textile raw materials and finished products.

Discussion of Papers Presented at the Textile Session

Two papers were presented at the Session on Textiles, held on the afternoon of December 7, 1926. They were: The Cotton Textile Industry, by Charles T. Main[2] and Frank M. Gunby,[3] and Tensile Testing of Textiles, by W. F. Edwards, appearing on the immediately preceding pages. The paper by Messrs. Main and Gunby was presented before the Old Dominion Meeting of the Society, September 27–30, 1926, but because of the importance of the subject it was again presented at this session.

In the oral discussion following the first paper, Frank W. Van Ness[4] referred to the suggestion that the northern mills turn to the manufacture of finer goods to increase their income. He could not agree with the authors on this, and pointed out the fact that the northern mills could buy raw materials just as cheaply as those in the South, but that the South could buy power at a considerably lower rate. The labor cost also would be considerably in favor of the South, he showed, as would the taxes on the property as well. He felt that the only possible chance for the North to effect a solution through the manufacture of fine goods would be to develop new styles in which there would be a larger margin of profit, rather than through the manufacture of staples. Mr. Van Ness also commented on the desirability of closer coöperation between the mills of the North and those of the South, and mentioned the work of the Cotton Textile Institute in bringing about this better relationship.

Regarding the fluctuation of prices, he said that the merchant was not so much interested in whether or not they were high or low, but whether or not they were uniform. Merchants often bought goods which in 60 days sold for less than what they had paid for them. He expected valuable suggestions for improvement from the Cotton Textile Institute.

H. M. Burke[5] wished to have a comparison of the number of spindles in the South making fine goods with the total fine-goods spindle in operation.

Regarding the number of spindles in operation, he mentioned the fact that the records showed that the rate of increase had exceeded the rate of population increase, and that with the spindles in operation it would take probably 75 or 80 years for the country to grow up to the spindle capacity.

He felt that the solution lay in the northern mills' turning to fine goods, or in a combination of interests that would weed out the unfit.

[2] Chas. T. Main, Inc., Engineers, Boston, Mass. Past-President, A.S.M.E.
[3] Associate, Chas. T. Main, Inc., Boston, Mass. Mem. A.S.M.E.
[4] President, Frank W. Van Ness & Associates, New York, N. Y. Mem. A.S.M.E.
[5] Plant Engineer, Mt. Hope Finishing Co., North Dighton, Mass. Mem. A.S.M.E.

He also wondered if it might not mean that the northern mills must eventually turn to the manufacture of something other than textiles. In referring to the question of merchandising, he stated that, in his opinion, the entire problem hinged on the question of labor; power, transportation, etc. playing a much smaller part than commonly supposed. He also mentioned the lack of understanding between manufacturers, who operated full force day and night to cut fixed charges, pushing production up and driving costs down, producing more than needed, as a contributing factor in the chaotic conditions existing.

Charles T. Plunkett[6] mentioned the fact that the southern mills were comparatively new in the main, having been built during the last eight or ten years. They had mainly been erected since the cost had been very high per spindle, and there was the question of whether or not larger profit must be had to compensate for the larger investment in their mills as against northern mills which had been in operation for many years and had been properly financed so that their machinery had been written off.

He was not prepared to say what the cost of a good northern mill would be as compared with a southern mill, the northern mill owners having had a good many years in which to reduce their investment below that of the southern mill, enabling them to earn enough on their investment to make it necessary for the southern mill to earn a good deal more to pay the same rate of dividends.

Mentioning the production of new lines, he said that it was a tremendous expense for any mill to produce a varied line of goods. It made the cost so high that when produced they could not be marketed. Many of the expressions regarding the lack of variety came from the merchandisers, he said, and they had little conception of what it meant to the manufacturer.

He did not feel that it was fair to say that the manufacturer had not given this a great deal of attention. He had known for years that if he made any profit it must be in his merchandising. There had not been a great reduction in the cost of making goods. There had been a better profit in some lines of goods than others, and that profit would persist for perhaps two or three years; then something entirely different would be necessary to meet the so-called demand of the people for something different.

It was a tremendous expense, he said, to change from one line to another, and if a mill must do it every two or three years, the profits which they expected would be used up in the change, leaving them no better off than they would have been had they not made the change. The only real justification for the change came from the fact that there were goods which could not be sold and therefore something that could be sold must be manufactured. Variety might add to the extensive sales of goods, he concluded, but it was done always at a very great expense, and it was a question whether that expense was always justified.

According to McRae Parker,[7] great strides were made in the reduction of power costs within the last decade; greater strides, he believed, than in the increase in production per operative of textile machinery. He felt that the future would show a greater increase in production per operative of textile machinery than the reduction of cost of power, thereby making the element of power a larger factor.

Mr. Burke, again referring to merchandising methods, argued that open price association would aid in the solution of the problem now confronting manufacturers who, although they made a small profit in the South, passed it right on to the consumer.

To illustrate the importance of power costs, Mr. Van Ness showed that a saving of 1 cent per kw-hr. in a 1000-hp. plant would amount to a total saving of $30,000 a year that could be passed to the stockholders as a dividend of roughly 10 per cent, assuming that such a mill would represent an investment of about $300,000.

In his closure, Mr. Main remarked that some of the suggestions which he had made for remedying the difficulties were not his own. With reference to the manufacture of finer goods in the North, he felt that there was being made all that could be consumed. He saw no reason why the finer goods could not be made in the South and the same relative savings made in the cost of production, as compared with the coarser goods.

[6] President, Berkshire Cotton Mfg. Co., Adams, Mass. Mem. A.S.M.E.

[7] Mechanical and Electrical Engineer, Cleveland Worsted Mills Co., Cleveland, Ohio. Assoc-Mem. A.S.M.E.

The fine-goods mills in the South were about one-tenth of the total number of spindles, and in the North about one-third of the total number of spindles, he said, in answer to Mr. Burke's inquiry.

He gave as his reason for not stressing the item of power more the fact that every one else was talking about it. Transportation and power, he added, were the chief topics of discussion, but the greatest item of difference, the cost of labor, was forgotten.

He did not wish it understood that he minimized the cost of power in manufacturing, however, but it was his belief that the item of labor, the importance of getting a proper number of people to run the mills, who would be contented in any location, was of vastly more importance than the item of power.

Referring to Mr. Plunkett's remarks, he said that many of the older men in New England were bringing up the same argument against moving to the South, namely, the greater cost of manufacturing in the new mills due to the high cost of developing and building the mills, as compared with the low capitalization of the older mills in the North.

He deplored the tendency of the southern mills to "kill the goose that laid the golden egg" by running overtime and piling up goods and then having to dispose of them to get capital quickly.

It was his opinion that if they would sell their goods at a fair profit, they could earn dividends on a mill costing, say, $60 a spindle, and in addition reduce their capitalization each year to get it down to a more reasonable capitalization, as compared with the North, of $30 a spindle. The trouble in the North, he said, was that some of the mills could earn nothing with a capitalization of zero. Regarding the effect of location, he mentioned the case of a mill in New Bedford, Mass., which, losing 1 cent per pound on all goods manufactured, moved the spindles to Texas and made a profit of 5 cents per pound with the same machinery and the same management.

He agreed with Mr. Plunkett's remarks on styling, and mentioned his experiences over several years in a mill where many styles and patterns were made, about $100,000 going into changes in styles each year.

Although he regretted the tendency to move to the South, Mr. Main felt that the ultimate outcome would be that those mills producing coarse and medium goods in the North with old machinery and old buildings and no quick capital would have to liquidate. Machinery worth moving would be moved quickly to the South, thereby reducing the number of spindles somewhat with no tendency to increase the total number of spindles in the country. The finer-goods mills, he felt, would stay in the North, as well as some of the coarser-goods mills that were properly equipped and had some money to carry them over the depression.

In the discussion of Dr. Edwards's paper, James W. Cox,[8] Jr., mentioned the practice of testing cloth and classifying it according to the average strength, as, for instance, 80 lb. average. It was his contention that since the cloth was used in pieces, the actual piece used might test as low as 50 lb., yet the average strength of the entire piece would be 80 lb. He recommended that the average minimum strength be used, as in that case there would be no doubt that the cloth would be good for the stress specified. He also emphasized the importance of making the cloth evenly. In other words, if the yarns were uneven, the average strength might be 80, with a minimum of 60 and a maximum of 100. If they were even, and a good piece of cloth was woven, yarns of less strength could be used and still the minimum strength of the cloth would be good enough for the purpose. It would be a cheaper cloth to make and better for the purpose for which it was intended.

Another point touched upon by Mr. Cox was the percentage of stretch before breaking. As an example of the importance of the subject, he mentioned conveyor belts and polishing cloths, which, if they would stand no strain without stretching, were valueless. In the rubber trade, where cloths were impregnated, he showed that it was necessary to know the elasticity of the cloth: the number of times it would stand a given load without stretching.

He did not feel that the method of testing fabrics was of much importance, so long as the same method was used in all tests; neither did he feel that it mattered whether or not the temperature and humidity were kept constant. The primary factors, he main-

[8] Consulting Textile Engineer, New York, N. Y. Mem. A.S.M.E.

tained, were the evenness of the finished cloth and the minimum stretch, elasticity, or breaking strength of the particular fabric for the particular use to which it was put.

In his closure, Dr. Edwards said that in his judgment the question raised by Mr. Cox was one of the fundamental reasons for becoming more and more accurate in our testing methods. Although, he said, those who did any amount of testing were fairly certain that they should pay just as much and perhaps more attention to extremes than to averages, those who were doing testing every day also paid attention to another thing, namely, the average deviation from the average; that was to say, the average of the deviation above the average, and the average of the deviation below the average.

As an example, he assumed a yarn with an average breaking point at 40. The majority of the breaks occurred below 40, but there were enough high breaks to bring the average up. Taking the average deviation from the average, this yarn, then, was not a 40, but really in effect some yarn lower than 40, having a test running most of the time on the low side instead of a goodly portion of the time on the high side.

He urged that more data be collected on the tensile testing of various products, and that these be carefully examined to determine the present status of the work.

Speaking of his personal experiences, he said that when he asked questions regarding the reasons for making certain tests he almost invariably received a hesitant answer. There didn't seem to be enough known about the relation of the product being tested and the test itself. Such a collection of data as just mentioned, he felt, would do much to relieve this undesirable condition.

At the request of Mr. Cox that he discuss the relation of stress and elasticity to strength in the warp industry, H. V. W. Scott[9] explained that in the knitting of rayon the elasticity and tensile strength were particularly important. To obtain the desired elasticity it was necessary to soak the rayon; also, various tests with different silking formulas had been made to arrive at one that would give the elasticity needed for a particular knitting machine or knitting operation.

As far as silk was concerned, he said, the chief interest in testing was in evenness, since the sale of chiffon hose was dependent on the clearness of the stocking. It was his opinion that there had been more money expended and more tests made in the last year on evenness of silk yarns than in any previous year.

As to cotton, he stated that here again elasticity and strength were the essential tests in knitting. As in the case of rayon, the cotton yarns must be soaked to produce the elasticity needed for warp-knitting operations, since at all times the yarn was under a greater tension than in ordinary flat knitting.

Dr. Edwards in his reply referred to the confusion likely to result from the use of the word "elasticity;" "stretch" was the correct word. The word was one borrowed from Europe, which even the younger men in the silk industry used when they meant elongation. Since rayon had come into general use, there had been a great deal of misunderstanding growing out of the confused use of these two words, "elongation" or "stretch" and "elasticity." He urged all to use the same language for the sake of clearness.

David Scott[10] mentioned automobile tire cord, which he termed a magnified warp. He explained that it was not used as woven fabric, the plies of a tire being laid at right angles to each other. He showed that elongation of the cord was an important factor, and that a great many of the specifications for that cord were written on a basis of the elongation of the single yarns at 10 lb. load. The combined strength of a tire was many times what it would ever be called upon to stand in its original state, he said, but in the balloon construction, flexibility and resiliency of the tire were important. To secure this flexibility, the tire in the process of manufacture was put on an air bag which expanded in the mold under heat and stretched the cords.

He then explained that if those cords were not of an even stretch, a scalloped effect on the inside of the tire resulted. If they were of a reasonably uniform stretch, then the impregnation of the cord by the rubber produced a resilient cord, approaching what should be termed "elasticity," or the power of the cord to recover and thereby to absorb the road shocks.

In closing, Dr. Edwards called attention to the fact that the elongation of the cords mentioned by Mr. Scott was, as a rule, 4 to 6 times the elongation that could be obtained from the singles from which they were made. This was due to the cable twist employed, he explained, but the average user of these cords was not familiar with the mechanism of the cords they were using, he added.

[9] Manager, Van Raalte Co., Paterson, N. J. Jun. A.S.M.E.

[10] Henry L. Scott & Co., Providence, R. I.

The Most Important Thing in Welding[1]

FUSION welding is in no way different from any other operation, because any operation can be either a success or a failure. It is true that the manipulation of the welding blowpipe is different from that of a lathe or other machine, but the same principle underlies both operations. Stated briefly, it is that the procedure used must be correct if success is to be desired, and it is at once evident that as procedure involves a number of elements, each one of them must be correct if the process is to be successful. In general, the following elements may be considered as essential to procedure, regardless of what is being made: Design, materials, methods, operators, supervision, and tests.

I might elaborate at great length on each one of these items in connection with welding, but I will content myself with putting into as few words as possible what I have to say.

Design. This must be such as will enable the welder to weld easily and cheaply and to do good work. Designs suitable for other forms of joining than welding are frequently very unsuitable for welding, and it is necessary for the designer to forget the other types of joinings, and to learn to use those suitable for welding.

Materials. These must be such as will result in clear, sound welds, so that both the base metal and the welding rod must be selected with this in view. Also the welder must be considered, because while he may be able to use materials that are hard to weld, and while it might be necessary in some cases to do this, yet for general work, this should be avoided, and materials should be selected accordingly.

Methods. This refers particularly to the use of suitable jigs, fixtures, clamps, and other tools, and to the order and way in which the various parts of the whole operation, including the preparation and finishing, are performed. Any of these things that make it easier to get better work, are an advantage, and each design should be studied with this in view.

Operators. As in all other cases, much depends on the operator, but if he is handicapped by improper design, materials, or methods the best results cannot be expected, no matter how good he is. I disagree with the idea that the operator is the most important link in the chain. I do not think that any one of the items mentioned is of superior importance to the others.

Supervision. As in any other work, competent and careful supervision is necessary and the supervisors must be competent to perform their duties. The supervisor should know not only the actual welding operation, but all other parts of the work.

Tests. A weld cannot be inspected internally to determine its quality, but it has been amply demonstrated that tests can be devised that will prove the integrity of the welded structure, provided the other links in the chain receive the proper attention. There are many other structures to which the same statement applies. One of the best illustrations is concrete. There is no way of inspecting the interior of concrete, and procedure control in its construction is necessary and has been carried to a very high degree of development. The testing of concrete structure is done in practically the same way that welds are tested, by applying a test load of more than the normal working load, and it has been found by experience in both concrete and welding work that when the procedure is proper, safe results are always obtained.

Procedure control in welding has shown its value in many cases not only in better work, but in reducing the cost and increasing the production. I strongly believe that it is the most important thing in welding.

[1] Paper presented at the International Acetylene Association Convention, Chicago, November 11, 1926, by S. W. Miller, Consulting Engineer, Union Carbide and Carbon Research Laboratories, Inc.

Industrial Applications of the Flettner Rotor

Characteristics of Rotor and Its Suitability for Application to Wind Wheels—Particulars of Proposed 100-Ft. Wheel with Savonius Rotors to Generate 183 Hp.

By F. O. WILLHOFFT,[1] NEW YORK, N. Y.

THE Flettner rotor is a mechanical device which, when placed in the current of a fluid, produces a force nearly at right angles to the direction of flow. In its action, therefore, it is very similar to the airplane wing, and, as in the latter, the component perpendicular to the direction of flow is very large compared with the component parallel thereto. These components will be called lift and drag, respectively, not merely for simplicity's sake, but in order to emphasize the analogy between the rotor and the airplane wing.

In his book on the rotorship[2] Anton Flettner gives it as his opinion that for the modern engineer the important thing is not so much to find the solution of a problem—which is comparatively simple if he is properly equipped—but to recognize clearly economic needs and to formulate precisely the problem.

It seemed to Mr. Flettner, as it had to countless others, that it was highly uneconomic not to make use of wind power, which is available, free to all, in billions of horsepower on land and on sea. He therefore set out to improve on the methods of utilizing wind power which had been in use for time immemorial without any material changes, and to apply to them his thorough knowledge of flow laws, utilizing the splendid facilities of the Aerodynamic Laboratory of the University of Göttingen, supplemented later by his own wind-tunnel equipment. Thus he confirmed his theories and established the coefficients which enabled him to decide on the proportions of his first rotorship, and which practical experience with the ship has proved to be correct to a remarkable degree of accuracy.

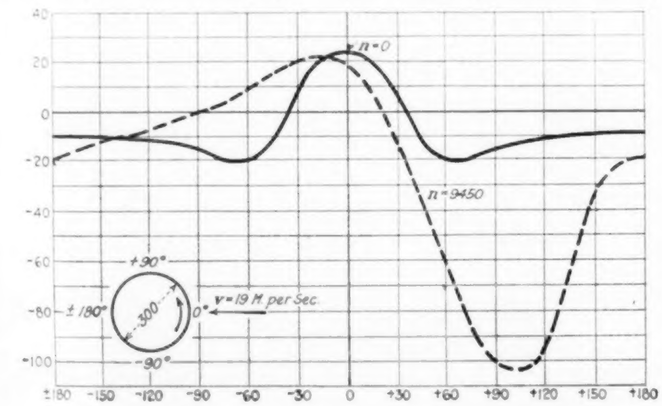

Fig. 1 Distribution of Pressure Around Rotor

The analogy between airplane wing and rotor has already been mentioned. In each case a majority of the streamlines are deflected to one side of the body so that on that side acceleration of the fluid takes place with a corresponding reduction of pressure, and on the opposite side there is a tendency for the fluid to be retarded, with a resulting slight increase of pressure, the vacuum being much more pronounced than the pressure increase. In each case the result is a "lift" component acting upon the projected area of the body. In the case of the airplane wing the deflection of the streamlines is effected by pushing a suitably shaped curved section through the air, while the rotor is revolved about a fixed axis, thereby continually offering a fresh surface to the wind and making the action continuous. The action of the wind on a rotating curved surface has been named the "Magnus Effect," which, in a sense, is unfortunate because people thereby receive the impression that they are dealing with a very mysterious force for which a brand-new theory has to be evolved. Nevertheless, Professor Magnus was the first to undertake an experimental investigation of this deflecting action which had long been observed on projectiles and later on tennis and baseballs, and it is only fitting that his name should be associated with the phenomenon.

For the airplane wing, as well as for the Flettner rotor, the formula for the total resultant force has the form:

$$R = {}^1/_2\, C\rho A V^2$$

where A is the projected area, ρ the density of the fluid, V the velocity of the fluid with respect to the body, and C a coefficient depending upon the characteristics of the body and, in the case of the airplane wing, upon the angle of attack and aspect ratio, while for the rotor the coefficient varies also with the ratio of peripheral velocity to fluid velocity.

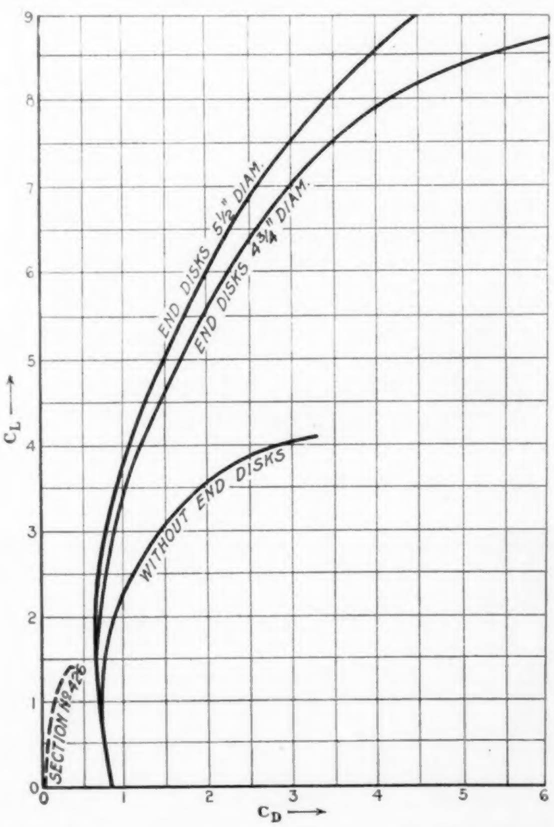

Fig. 2 Typical Polar Diagram of Flettner Rotor, Giving Lift and Drag Coefficients with Constant Wind Velocity and Varying Peripheral Speed

It is well known that for an airplane wing the vacuum on the upper side is responsible for from 60 to 80 per cent of the total lift. Similarly, the vacuum on the side of the rotor where surface and current travel in the same direction accounts for about 80 per cent of the total lift (see Fig. 1), while the remainder is furnished by the pressure increase on the opposite side where the cylinder surface moves in a direction opposed to that of the current.

Characteristic Diagrams of Flettner Rotor

There are three characteristic diagrams of the Flettner rotor which have been published in various articles on the subject, and which are absolutely essential to an understanding of the rotor action. The first is the typical polar diagram, Fig. 2, giving the lift and drag coefficients of a rotor, the wind velocity being constant and the peripheral speed varying. In the lower left-hand corner

[1] Consulting Engineer. Mem. A.S.M.E.

[2] Mein Weg zum Rotor, Leipzig, 1926. Published in English under the name The Story of the Rotor, by F. O. Willhofft, 68 Beaver St., New York.

the lift-drag curve for a good airplane section is shown. If the curve for a sail under the most favorable conditions had also been included, it would be seen that the lift coefficient of a sail does not even reach the value 1. The diagram illustrates the surprising superiority of the rotor over sail and airplane wing as far as lift is concerned. The drag, of course, is considerably greater, as would be expected.

In the second curve, Fig. 3, the lift is plotted against the ratio $u:v$, u being the peripheral speed of the rotor and v the wind velocity. The curve illustrates most strikingly how very rapidly the lift increases as the cylinder is accelerated, and reaches a maximum when the peripheral speed rises to about $3^1/_2$ or 4 times the wind velocity.

The third characteristic curve, Fig. 4, gives the total pressure against the two rotors of the rotorship *Baden Baden*, plotted against

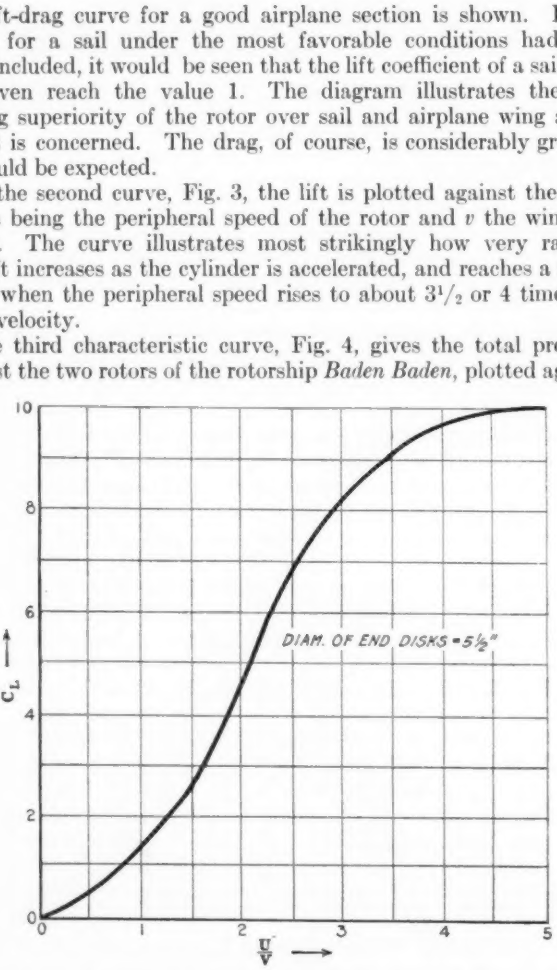

FIG. 3 LIFT PLOTTED AGAINST RATIO OF PERIPHERAL SPEED TO WIND VELOCITY

wind velocity. The upper curve represents conditions when the rotors are turning at a constant speed, and the lower one when they are stationary. For the particular conditions selected, the pressure against the rotors ceases to increase after the wind has reached a velocity of about 27 m.p.h.

A study of the three characteristic curves plainly indicates the field of application of the rotor. Its characteristics may briefly be summed up as follows:

1 It has a very large lift compared with a curved surface such as the sail of a ship, or even with the heaviest-lift airfoils.

2 Its resistance in the direction of the wind, i.e., the drag, is much larger than for an airplane wing and the lift-drag ratio is relatively low, but the resistance is not excessive when dealing with a natural wind.

3 By varying the speed of rotation, the total pressure exerted by the wind upon the rotor at any given wind velocity, i.e., the resultant of the lift and the drag, may be varied between the minimum when the rotor is not revolving and the maximum which depends upon the speed with which the rotor is made to revolve but which in any case does not exceed the value reached as soon as the peripheral speed becomes a certain multiple of the wind velocity.

4 By laboratory and practical experience it has been found that the power required to revolve the rotor at the velocity giving maximum lift is less than 10 per cent of the energy abstracted from the wind. By improvements in the design it is reported that this figure has been considerably reduced in the latest rotor installations.

Fields of Application of Rotor

In the light then of this information, what are the fields of application for the rotor?

Although the term "wind" has mostly been used in this discussion, the rotor will of course work in any fluid. It could be used as a water propeller, substituting for the propeller blades cylinders rotating about their longitudinal axes. As a matter of fact, Flettner reports that Professor Föttinger, who is best known in this country by his hydraulic clutch, had such a propeller constructed, but merely to demonstrate the Magnus effect. On account of its relatively high resistance in the direction of motion, this propeller would hardly prove practical. The same may be said of the proposal to furnish the lift for airplanes by means of rotors, the lift-drag ratio of regular airfoils being so much more favorable, although its application to the helicopter type of airplane might have certain advantages.

The use of rotors for ship propulsion in place of sails is outside the scope of this discussion. The first rotorship, the *Buckau*, later named the *Baden Baden*, proved to every one's satisfaction that technically the ship's rotor is entirely practical. In the wind and sea such as she encountered in the North Sea in midwinter, as well as on the Atlantic where she also passed through terrific storms, the rotors proved to be entirely safe, reliable, and efficient. As far as power is concerned, the rotors accomplish exactly as much as sails of about ten times the area formerly did, and under certain conditions are superior to them, but in place of the crew which handled the sails before the ship was converted, there is an electric controller on the bridge for each of the rotors, and a slight movement

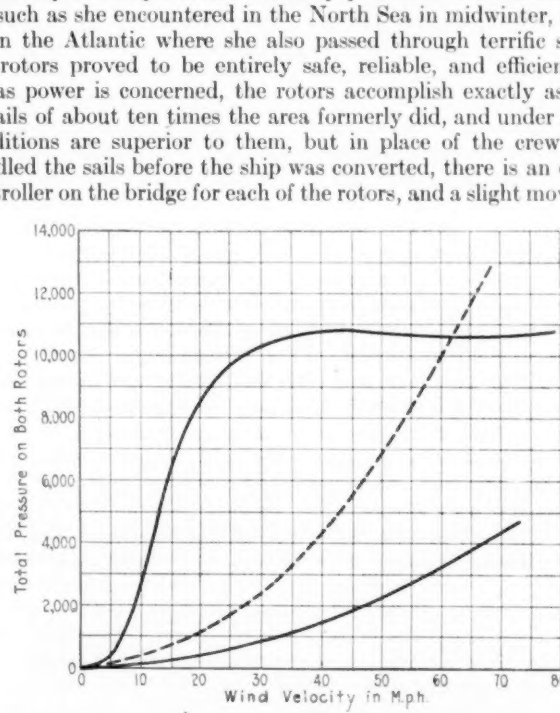

FIG. 4 TOTAL PRESSURE ON THE TWO ROTORS OF THE ROTORSHIP "BADEN BADEN" PLOTTED AGAINST WIND VELOCITY

of the handle is all that is required to "set sails" or "go about," or make whatever maneuver may be desired.

The second rotorship, the 3000-ton *Barbara*—the first ship actually built as a rotorship—is in regular commercial service and has already made two voyages. According to the reports received, her performance is everything which her designers and owners anticipated. The future development of the rotorship may be left to the shipbuilders and shipowners.

As far as application on land is concerned, the question at once suggests itself: How can the rotor be applied to windmills, and what are the economic possibilities?

Application of Rotor to Windmills

In order to answer this question intelligently we must first briefly survey the present state of the art and define the factors which have tended to retard its development. The windmill is thousands of years old, and yet, generally speaking, the maximum amount of power produced by any one unit is not more than 10 to 15 hp., and the average capacity of windmills in this country is so low that manufacturers do not even quote the capacity in horsepower, but in gallons of water pumped. Any one who has not had occasion to inform himself will be surprised to hear that, according to U. S. Government statistics, about 100,000 windmills are sold every year. And yet, from an engineering point of view, there is so little of importance to report that a well-known handbook of mechanical engineering, containing over 1900 pages of reading matter, has slightly more than one page on windmills. In Europe where, for well-known reasons, engineers have gone in for greater refinements in the generation of power, even at the sacrifice of simplicity, more

attention has been paid to the development of the windmill than in this country where, for the purposes for which windmills are used at all, low first cost, simplicity of operation, and reliability outweigh everything else. Since the input is supplied by nature free of charge, efficiency, at least at present, is of minor importance.

The two reasons why engineers in general have devoted so little time and thought to the wind wheel are, first, that the wind is considered very unreliable and may vary at any time between nothing and 100 m.p.h., and secondly, that the theoretical horsepower of a windmill varies as the square of the diameter and as the cube of the wind velocity. Thus, assuming that a certain windmill has been designed for the average wind velocity in a given locality, say, 10 m.p.h., the horsepower at 60 m.p.h. would be 216 times as great, and the stresses would increase correspondingly. It would be manifestly absurd to try to build a wheel to withstand these stresses, since the cost would be prohibitive, hence other means were adopted so that the wheel could be sold at a reasonable figure and still would not be destroyed by a hurricane. Such means consisted in turning the whole wheel out of the wind, revolving the sails on their longitudinal axis, employing shutter-like sails, etc. Nevertheless, the windmill builders do not offer wheels larger than about 50 ft. in diameter.

The design of windmills in the last 25 years has gone through the following stages: The standard "American" windmill, as it is called in Europe to distinguish it from the old Dutch and German windmills, consists of a turbine wheel with numerous blades, nowadays generally curved steel blades. Since the relative velocity of the wind with respect to blade varies with the distance from the center of the wheel, the blades are twisted so as to secure the proper angle at each point, or are made in sections having different entrance angles. The next improvement consisted in having a smaller number of blades for the same size of wheel, with the result that the flow conditions behind the blades were improved, and thereby the efficiency. At the same time the speed was increased, i.e., the wheels could be made lighter for the same horsepower, but this was done at the sacrifice of the ability to start at low wind velocities. In other words, while the old wheels started under load at a wind velocity of, say, 5 m.p.h., the high-speed wheel would not start below 7 m.p.h., a serious disadvantage for the ordinary pump wheel, while the increase in speed at average wind velocities is so much more important where an electric generator has to be driven. The velocity of the wing tips used to be about twice the wind velocity, and on the high-speed wheels has been increased to three times the wind velocity and even higher.

Fig. 5 First Large Rotor Windmill to Be Built

[Wheel diameter, 65 ft. 8 in.; height of tower, 108 ft.; rotors 16 ft. 5 in. long, and $35^1/_2$ in. ($27^1/_2$ in.) in diameter at outer (inner) end.]

Finally, regular airplane-propeller sections were substituted for the turbine blades and the number of wings reduced to six, four, or even two. This resulted in greater efficiency and higher speed but still more unfavorable starting conditions, so that a wheel of this sort would not begin to turn below 7 to 9 m.p.h.

This is the point where Flettner's work set in. He had studied the windmill problem for years and had carried on extensive experiments. As a result he had come to the conclusion that a wheel with wings built on the plan of the current-actuated free rudder would be superior to all the existing types in efficiency and ability to start at low wind velocities, and on the other hand to withstand the highest wind pressures. The wings, shaped like airplane wings, were to be free to rotate about their longitudinal axes and to be controlled by small auxiliary planes pivoted at the tail edge exactly as on the well-known Flettner rudder for airplanes and ships.

Fig. 6 Another View of Rotor Windmill Shown in Fig. 5

Just at that time, however, the *Baden Baden* had established the practicability of the rotor, and especially its wonderful inherently automatic regulation which enabled it to withstand any kind of storm. Hence, after further investigation, it was decided to use the rotor for the first large windmill to be built. (See Figs. 5 and 6.) This windmill has now been in successful operation at the works of the builders for over three months and, according to the reports received, has established the soundness of the rotor principle for windmills just as the *Baden Baden* did for rotorships.

The wheel has a diameter of 65 ft. 8 in. The tower is 108 ft. high. The four rotors each have a diameter of $35^1/_2$ in. at the outer end and of $27^1/_2$ in. at the inner end. They are 16 ft. 5 in. long. The shells are made of $^1/_{32}$-in. aluminum alloy. Each rotor is driven by a small motor built into the inside of the shell.

The housing at the top of the tower contains the electric generator which is driven by the wheel through a 1:100 transmission. The generator is of a special design giving constant voltage at widely varying speeds. It feeds either into the line or into a storage battery.

Suitability of Rotor for Wind Wheels

Let us now consider why the rotor is so eminently suitable for wind wheels.

The vital importance of the ability to start at low wind velocities has been pointed out, also how this characteristic has been partially sacrificed in other modern designs of windmills in order to gain higher speed and weight reduction. If it is further remembered that the lift of the Flettner rotor increases with the ratio u/v, or that of peripheral speed to wind velocity, it will be seen that the rotor in this respect is an ideal device. Before the wind wheel starts to turn the rotors begin to revolve, and if the speed of rotation is correct we have the ideal conditions for maximum lift. As the

wheel begins to turn, the relative wind velocity increases so that unless the turning speed of the rotors is increased, conditions, become less and less favorable, and the lift, i.e., the tangential effort, gradually decreases, until the speed corresponding to the load and to the wind velocity is reached. As Flettner very aptly expresses it, the windmill rotor, when the wheel is started, takes the place of very wide or a large number of wings, and as the speed increases the effective area shrinks, so to speak, until at normal speed the rotor corresponds only to the narrow propeller wing of the ordinary four-wing wind wheel. This explains why the rotor wind wheel is a medium-speed wheel, its wing-tip velocity being about $2^1/_2$ times the wind velocity.

The second vital difference from and advantage over other types of windmills is represented by the characteristic previously mentioned, namely, that the rotor wind wheel need not be turned out of the wind when the wind strength exceeds the value for which the wheel has been designed. Quite on the contrary; even if the wheel has been designed for a wind velocity of only 25 m.p.h. and the velocity increases beyond that figure, we can continue to abstract the same amount of energy from the wind as we abstracted at 25 m.p.h. In other words, no matter how much the wind velocity increases, the speed of the wheel remains constant after it has reached the maximum value for which it was designed.

Another valuable characteristic of the rotor wheel is that the rotor always, and along its whole length, is in the most favorable position with respect to the wind. This will hardly be claimed even for the most carefully designed wing of the curved-plate or propeller type.

While it is quite true that the wind is unsteady and irregular, one is apt to overemphasize this bugbear of wind power. Sufficient statistics are available nowadays so that it is possible to form accurate ideas about wind-strength averages in different localities. Conditions of course vary widely in different parts of the world and in different parts of each country, but in order to illustrate the general characteristics it will be of interest to examine the curves

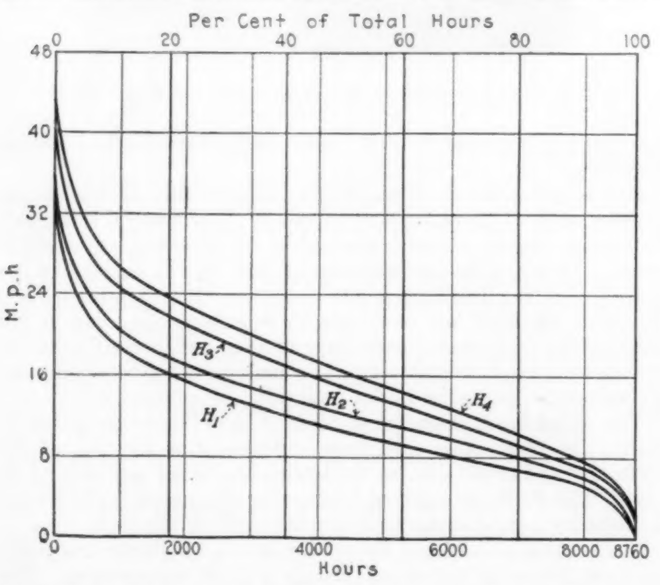

Fig. 7 Wind Velocities at Wireless Station, Nauen, Germany, at Different Heights Above Ground

based on observations made at the well-known German wireless station of Nauen at different heights above the ground (Fig. 7), and representing the averages of two years of observation. The curves give the wind conditions at heights of 53, 106, 265, and 410 ft., respectively. They show first of all the great advantage of placing the windmill as high as possible, and in this connection it must not be forgotten that if the wind velocity increases only, say, 20 per cent between 106 and 265 ft. altitude, the horsepower of the wind motor increases as the cube of the wind velocity, or in this case about 75 per cent, against which has to be charged the increase in first cost of the tower. It will further be noted that if the wheel is designed to start at, say, 7 m.p.h., it will be standing still less than 10 per cent of the whole year.

Another important fact is brought out by these curves. Wind wheels which have to be turned out of the wind as the wind strength increases above a certain point lose another part of the curve at the upper extremity, which is not the case when rotors are used, as previously explained.

Just as the ship's rotor would not have been practical before the

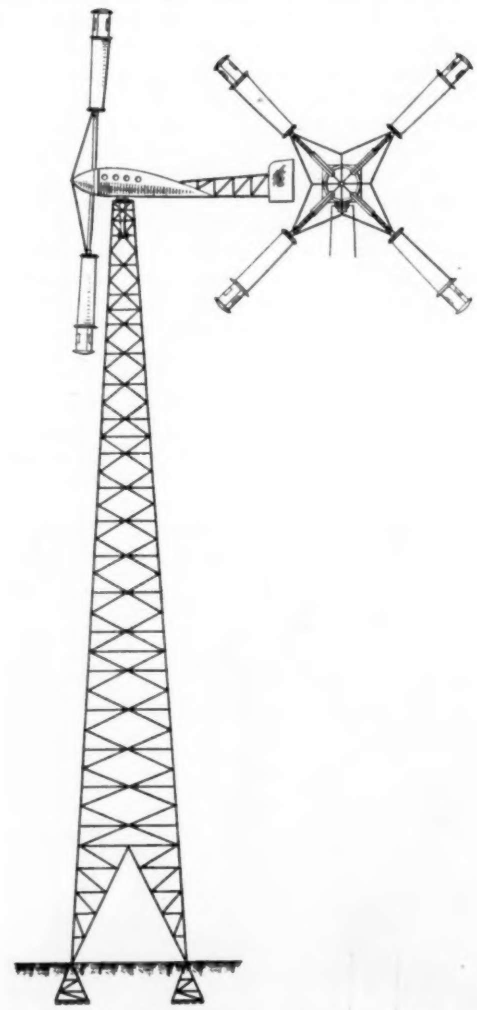

Fig. 8 Proposed Wind-Power Plant with 100-Ft. Wheel

state of the art had sufficiently advanced so that they could be constructed without being excessively heavy, so the feasibility of building Flettner-rotor windmills in large sizes depends upon other branches of engineering.

The rapid development of wireless transmission has taught us how to build high towers of comparatively light weight and low cost. The aeronautic and the automobile industries have been responsible for the production of light metals, especially aluminum alloys, and large-scale production has brought with it lower prices. Sufficient experience in the working of these metals is also available today, so that practically every construction which is possible in iron or steel can also be executed in aluminum alloys. This is of vital importance for the construction of the Flettner rotor. The electrical industry has contributed a generator which maintains constant voltage at widely varying speeds. Hence Flettner's claim that there are no serious difficulties in the way of building rotor windmills of practically any size would seem to be justified by facts.

Proposed 136-Kw. Wheel

On the basis of the experience gained with the first 66-ft. wind-power plant it is proposed to build as the next unit the 100-ft. wheel shown in Fig. 8. While the rotors of the first wheel were driven by electric motors, a system which allows of perfect regulation and was quite necessary in the first installation to establish the best operating conditions, but which complicates the plant and increases the first cost, it is proposed to build all wheels in the future

with Savonius rotors attached rigidly to the ends of the main rotors. The Savonius rotor has been described in MECHANICAL ENGINEERING[3] so that it will not be necessary to discuss its construction and characteristics. The use of this device does away with all electricity as far as the rotors are concerned, so that a rotor windwheel used exclusively for pumping will be a purely mechanical apparatus just as is the turbine type of windmill pump. The regulation also will be extremely simple, since all that is re-

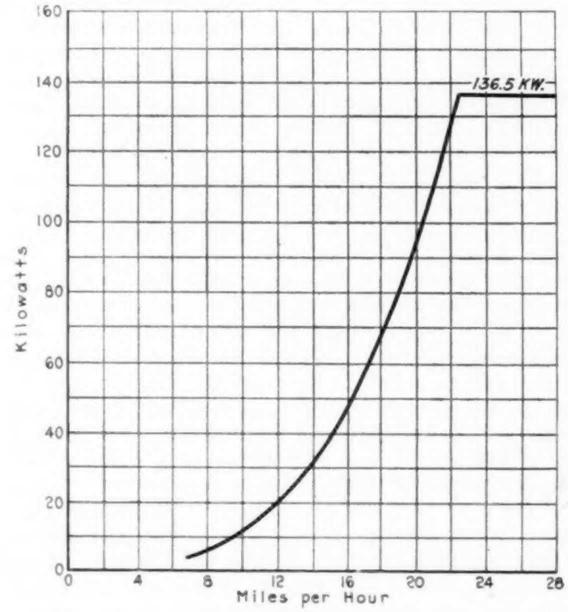

FIG. 9 POWER CURVE FOR A FLETTNER ROTOR WINDMILL 100 FT. IN DIAMETER

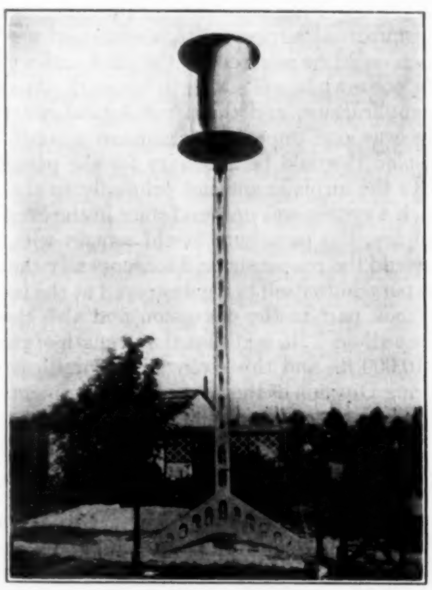

FIG. 10 MOUNTING OF SAVONIUS ROTOR FOR PUMP DRIVE

quired is to provide some pivoted flaps in the wings of the Savonius rotors which will begin to open and check the speed increase as soon as the wind velocity exceeds a certain amount, the opening being resisted by springs.

It would be rash for any one to predict what the limit in size for such wind wheels will be. A 350-ft. wheel, at a wind velocity of 18 m.p.h. would generate more than 1000 hp. The Savonius rotors for a 100-ft. wheel are 8 ft. 2 in. high and have a mean diameter of 4 ft. 11 in. The main Flettner rotors are 24 ft. 8 in. long and 4 ft. 7 in. diameter at the inner end and 5 ft. 11 in. at the outer end. In the streamline housing are the 1:150 transmission and the electric generator. The tower is planned to be 265 ft. high.

[3] Vol. 47, no. 11, November, 1925, p. 911.

This 100-ft. wheel will have a characteristic curve approximately as shown in Fig. 9. The maximum output for which the wheel is designed is reached at a wind velocity of about $22^1/_2$ m.p.h. and amounts to 136.5 kw. With increasing wind strength the output remains constant at this figure.

A wheel of this sort may be used in conjunction with a storage battery, or with an oil engine, or it may pump into a reservoir which takes the place of the storage battery, or it may feed into an existing line. Whichever combination will be used in any case will depend on the local conditions, but it can hardly be denied that such a wheel will find a wide field of usefulness.

The Savonius rotor, a modification of the Flettner rotor, can of course be used by itself, but in that case will be mounted as shown in Fig. 10, driving a vertical shaft which again serves as drive for a pump. In this form it will compete with the ordinary domestic-size windmills.

Another interesting application (Fig. 11) has been found in the combination of a Savonius-type rotor with an ordinary propeller fan for the purpose of ventilating closed vehicles, such as motor buses, closed private cars, motor boats, railway passenger and refrigerator cars, etc. This is far superior in capacity, particularly at low velocities, to all devices which depend only on the suction produced by the velocity of the wind, natural or artificial, and it will even operate when the vehicle is standing still, as long as the lightest kind of breeze is blowing.

Discussion of Papers Presented at Session on Aeronautics

AT THIS session of the A.S.M.E. Annual Meeting, held on December 9, with Charles L. Lawrance, president of the Wright Aeronautical Corporation, in the chair, three papers were presented: The Fusion-Joining of Materials in Aircraft Construction, by Samuel Daniels; Development and Construction of the Standard Army Parachute, by John Bonforte; and Industrial Applications of the Flettner Rotor, by F. O. Willhofft.

The papers by Messrs. Daniels and Bonforte appeared in the Mid-November, 1926, issue of MECHANICAL ENGINEERING. The

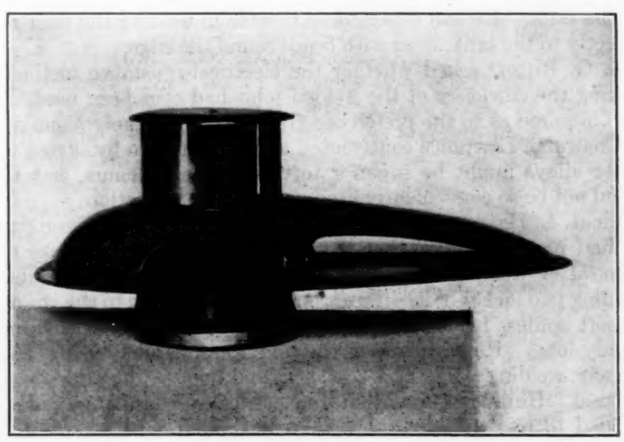

FIG. 11 COMBINATION OF SAVONIUS-TYPE ROTOR AND ORDINARY PROPELLER FAN FOR VENTILATING CLOSED VEHICLES

former consisted of a compilation of data available on electric and gas welding and brazing as applied to the joining of aircraft parts. The latter paper described parachute tests, explained the construction of the modern chute and developments in recent years, and pointed to possible improvements in the future. Mr. Willhofft's paper appears on the pages immediately preceding, and a summary of the discussion on all three papers follows.

THE FUSION-JOINING OF METALLIC MATERIALS

W. G. Harvey,[1] in a written discussion of Mr. Daniels' paper of the above title, stated that he differed from the author in regard to the welding of magnesium and its alloys. He had found that

[1] American Magnesium Corp., Niagara Falls, N. Y.

these alloys could be welded with but little trouble and certainly with no tendency toward rapid oxidation, provided excess heating was avoided and a flux used. The proper method was to bring the cleansed surfaces to be welded in close contact and to localize the heating in one spot at a time. A puddling process was then resorted to, using a highly heated steel wire, and this was effective in forming the initial joint, after which a magnesium or a magnesium-alloy wire was substituted for the steel wire and the cavities were completely filled. There was no trouble in making the metal flow provided sufficient flux was applied. All traces of flux had to be removed promptly from the weld or corrosion would set in. Mr. Harvey pointed out that practice in this stage was identical with that recommended by the author for aluminum. Washing with hot water, or preferably with a steam jet, was very satisfactory. A weld made in the above manner would be found solid, clean, and free from gas cavities. After a little experience an operator could weld magnesium alloys just as well as he could aluminum alloys.

Arthur Nutt[2] stated that his company used aluminum welding but very little owing to the fact that stressed parts should not be repaired in any manner. He had noticed the author's statement that no welding was permitted on castings which were heat-treated. According to the manufacturers of this material, a casting which was to be heat-treated could be welded provided the welding rod was of the same analysis as the casting and provided the heat treatment took place after welding. A casting welded and heat-treated in this manner would have the same strength as a sound casting. However, the practice was to be avoided on a highly stressed part. Mr. Nutt pointed out that one of the most satisfactory alloys for welding was the aluminum-silicon alloy used for thin castings for such parts as oil pans and handhole covers.

Archibald Black[3] asked whether there was any objection in welding a joint first and brazing near it afterward. He also wished to know whether any tests had been made to determine the safe load on soft solder which had been stressed for a considerable period of time under constant load.

K. M. Lane[4] suggested that chrome-vanadium sheet, which had about the same strength as chrome-molybdenum, might be well considered for welding purposes. In welding aluminum tanks, Mr. Lane said, it was very desirable to weld the filler neck to either a circular or rectangular sheet and then weld the sheet to the head of the tank. He had experienced trouble in welding the filler neck directly to the tank, even with beads round the edge.

J. G. Ritter[5] asked whether the electrical-resistance method of testing the efficiency of the welded joint had ever been used. He also inquired as to the preference given to chrome-molybdenum.

Chairman Lawrance contributed to the discussion by saying that other alloys might be superior to chrome-molybdenum, but they could not be so conveniently used in welded construction.

Lieut. L. Haase,[6] replying in behalf of Mr. Daniels, whose paper he had presented, said that it was perfectly proper to braze at a joint after welding, but that the Navy specifications prohibited welding two inches or less from a brazing. In regard to the strength of soft solder, he thought that it would ultimately yield under steady load. He approved of the practice described by Mr. Lane, namely, welding a filler neck to a sheet and then welding the sheet to the tank. He did not think that the electrical-resistance test had been applied to test the strength of a welded joint. In regard to the use of chrome-molybdenum steel, it was used because it could be brought up to a strength of 120,000 lb. per sq. in., and yet conveniently welded without the signs of cracking which might occur with chrome-vanadium steel.

Development and Construction of the Standard Army Parachute

In the absence of the author, Mr. Bonforte, this paper was presented by Lieut. Frederick M. Hopkins, Jr.[7] W. Laurence Le Page,[8] in opening the discussion, pointed out that the author had said that the load on the parachute might be as great as ten times the normal load. In the case of a man weighing 170 lb. this would be 1700 lb. Yet later in his paper he had stated that the maximum load on a parachute might be 2500 lb. and that the service chute actually had a factor of safety of 4, so that it would apparently withstand a load of 10,000 lb. Mr. Le Page wished to hear from the author with regard to these apparent discrepancies. He did not understand why the standard Army Air Corps parachute was made to withstand the shock due to a weight of 200 lb. falling at a speed of 400 m.p.h., which would necessitate a factor of safety far in excess of those stated previously. He also wished to know whether a speed of 400 m.p.h. could be approached in practice. Since the time between each exposure in the photographs of the opening of the parachute was approximately $^1/_2$ sec., a total of 5 sec. would be needed for the parachute to open completely. To a person falling, the shock of the opening might appear instantaneous, but from the pictures he would have judged that the load on the harness was by no means uniform and that this load probably reached a maximum during the interval between pictures Nos. 7 and 8, $3^1/_2$ sec. after the start of the drop. He wished to know whether any accelerometer experiments had been made in this regard.

Discussing the author's suggestion that in a large ship, where the crew had to move about considerably, parachutes might be suitably disposed at various points for their use, Mr. Le Page cited the accident of the British rigid airship R-38, constructed for the United States and wrecked in 1921 as a result of structural failure during violent turning trials. The crew of this ship was provided with harness, and parachutes were suitably disposed at various points. Some of the crew were able to jump with their chutes, others remained on board the ship in its descent. Five men were saved, and it was established that no one who had left the ship with his parachute was saved. The men with parachutes landed in the river Humber, and were smothered by their chutes owing to the absolute calm, and drowned. The fall of the partially deflated airship, on the other hand, was so slow as to give comparative safety. Mr. Le Page discussed the possibility of providing every passenger on board a commercial airplane with a concealed parachute under his seat, which could be released by the pilot and which would let the passenger down while still sitting in his seat. Apart from many structural complications, and the psychological effect on the passenger, there was one important argument against the scheme. In any such plan it would be necessary for the parachute pack to be attached to the airplane and not primarily to the passenger or his seat. Such a system was unsound since in the event of an emergency due to fire, the parachute would remain with the airplane longer than would the passenger, and consequently there would be a chance of the parachute itself being destroyed at the last moment.

Guy Ball[9] took part in the discussion and also closed it in the absence of the author. He said that the strength of parachutes was in excess of 10,000 lb. and this strength was well carried through. The Engineering Division of the Army had experimented with loads of 200 lb. dropped at speeds of 400 m.p.h. It had taken sixteen seconds for the pack to open. The noise made by a parachute opening up was like that of a pistol shot. Each parachute in production was tested with three twists put in the line. A twist was also placed close to the parachute. These twists were necessary because there was a probability of a man spinning as he left the airplane. The parachute when it started to open was inverted. As the walls came down, the shock attained its greatest value. In regard to the speed of fall of a man's body, this was estimated at about 275 m.p.h. It was hard to check this figure, because it was impossible to say what the exact attitude of the fall would be. Usually a man fell about three-quarters head down. Measured with a dynamometer, shock loads of 2000 lb. had been attained. In the modern parachute the fabric took no weight directly, but only withstood the air pressure. With regard to parachute landings on water, there was a column of air beneath the parachute and above it, and this unstable column would tend to make the parachute fall off to one side or the other. The vent in the parachute had been found to make no appreciable change in the rate of descent and the air apparently did not pass through the vent. The air flow in the parachute was in the form of vortices round the periphery, and this tended to hold the skirt out. Tests with confetti

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[6] U. S. N. Aircraft Inspection Service, New York.

[7] Air Unit Officer, New York University, New York, N. Y.

[8] Editor, *Aviation*, New York, N. Y.

[9] In charge of Airplane Construction, McCook Field, Dayton, Ohio.

and smoke tended to confirm this view. The Army Air Corps did not favor quickly detachable devices, because they involved dangers of too early an opening. The greater the speed of fall, the shorter the time of opening. It was a curious fact that a parachute which had a hole in it would never burst round the hole. There was no very definite information as to the rate at which the load varied with time during opening. It certainly would be desirable to have a uniform rather than varying shock load.

Industrial Applications of the Flettner Rotor

Discussing Mr. Willhofft's paper, Otto Lunde[10] gave the results of some experimental work he had undertaken in the wind tunnel of New York University, placing a rotor in the leading edge of an airfoil. The airfoil was a roughly designed curve, with the rotor as the leading edge, and with a flat undersurface. Graphs were obtained showing the difference in lift between the condition of stationary and rotating rotor. An increase in lift of some 17 to 18 per cent was obtained by rotating the cylinder, without any appreciable increase in the drag. This was an interesting phenomenon that might lead to further experimentation.

Alexander Klemin[11] stated that many of the claims advanced by the author for the rotor windmill could be met by windmills of the air foil or propeller type. If propeller windmills could be designed that departed from fundamental simplicity in the way the Flettner-rotor windmills did, very much better results than ordinarily obtained would be forthcoming. Professor Klemin said that he would undertake to treat this subject adequately in a short paper at a later date. He did not think the application of the rotor to the airplane likely, because the efficiency of the sustaining mechanism became very low. The combination of the rotor with an airfoil was more promising, however, than the use of a rotor alone, as experiments at the Daniel Guggenheim School of Aeronautics had indicated. He also referred to interesting German experiments along these lines. The subject certainly deserved further investigation. Inventors were busy devising various methods of securing the maximum circulation effect in the combination of cylinder and airfoil.

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[11] Professor of Aeronautical Engineering, New York University, New York, N. Y. Assoc-Mem. A.S.M.E.

Plating with Chromium

Effect of Spacing Electrodes on Throwing Power—Adherent Deposits Possible on Both Steel and Nickel—Maximum Thickness of Non-Peeling Deposit—Plating of Aluminum Difficult—Chromium Plating of Dies, Hard Rubbing Contacts, Gages, Etc.

The hardness and tarnish resistance of chromium, the bath used in chromium plating, the difficulties of obtaining a continuous, uniform deposit on articles of irregular shape, the cost per square foot of deposit, and the use of chromium plating on printing plates, gages, surfaces exposed to wear and corrosion, reflectors, etc., were discussed at length in a paper entitled Chromium Plating presented by William Blum at the Annual Meeting of the A.S.M.E. in December last, and published in the January issue of Mechanical Engineering, p. 33. Much interest was displayed in the author's statements regarding this recently proposed protective coating, and the many questions propounded during the discussion brought out from him considerable additional information on the process. A summary of this discussion follows.

U. A. Mullen,[1] who opened the discussion, asked how the hardness of chromium plating compared with that of heat-treated cyanided steel, and what the best conditions were for producing the hardness of the plating. On the sheets which the author had exhibited, the edges appeared to be in better condition than the center, indicating that they had received a better deposit than the center. How, he asked, would the conditions be fixed so that the center of a sheet would receive as good a deposit as the edges? Mr. Mullen also inquired whether the throw could be improved by decreasing the distance from the anode to the cathode or by increasing the distance, and whether the distance had any effect. He further asked whether in the chromium plating of tools for wear rather than for resistance to corrosion or for ornamentation, there was any preparation of the surface to prevent peeling of the plate, and whether there was any indication that chromium plating could be successfully used on cutting tools or on punches?

B. H. Blood[2] said that it had been suggested that plug gages after being worn to the limit could be restored to size by chromium plating. That raised the question whether one layer of chromium could be deposited on another, or, in trying to bring up the gage to a particular size, whether the operation could be stopped and the gage be measured and then put back in the bath for an additional plating.

R. S. Luce[3] asked whether the chromium deposit could be improved by burnishing, in the manner that articles coated by dipping in a tin bath were improved by burnishing or tumbling.

F. W. Van Orden[4] asked regarding the coefficient of expansion of chromium, and how it had been obtained, whether on chromium plate or on electric-furnace chromium. As to bathroom fixtures and plumbing fixtures, he said that all those in the new Presbyterian Hospital in New York, the largest in the country, were chromium plated, as were also those in a number of new hotels going up there and in other cities.

Jos. F. Keller[5] asked how thick it was possible to plate under normal conditions without peeling; whether there were any special precautions required to get thick coats; whether it was possible to plate readily with chromium on a polished surface in case it was desired to make a reflector; whether chromium would plate readily on most metals, for instance, aluminum; and whether the surface could be readily improved by polishing as in nickel plating.

A. E. Flowers[6] said that in considering the question of resistance of any plating to corrosion, it should be borne in mind that any electrolytic deposit was almost certain to be in either one of two unsatisfactory conditions. At its best it consisted of what might be called a laced structure, and at its worst, of a granular structure. In either case it was relatively porous as compared with any other condition of metal, particularly so in comparison with any hot dipping process, and in considering the question of chromium plating any article that had been previously plated, very serious thought should be given to making that previous plating by a hot-dipping method rather than by electroplating.

Mr. Flowers did not think it was quite as fully realized as it should be that the tinning process by the hot-dip method was vastly superior, with all its defects, to any other method of getting an impervious coat. The tin coat was in itself so resistant to penetration that the gases that were occluded or dissolved in the interior of the metal would come gradually to the surface, come up under the tin coat and lift it in what were sometimes called blisters, and yet not break through unless they became quite large in size. The defect of the tin coat was that it was impossible to get an absolutely continuous surface, due usually to some metallurgical imperfection in the material underneath, which might be a spot of some kind, an occlusion, a bit of slag, or any other condition which would prevent the initial operation, which was an alloy-

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[2] Hartford, Conn. Mem. A.S.M.E.

[3] Secretary and Treasurer, P-W Device Corp., Brooklyn, N. Y. Assoc-Mem. A.S.M.E.

[4] Sales Engineer, Green Fuel Economizer Co., New York. Assoc-Mem. A.S.M.E.

[5] President, Keller Mechanical Engineering Corporation, Brooklyn, N. Y. Mem. A.S.M.E.

[6] Engineer in Charge of Development, DeLaval Separator Co., Poughkeepsie, N. Y. Mem. A.S.M.E.

ing of the tin with the steel to form a sub-base to a pure-tin coat on the surface.

D. H. Chason[7] asked how a drawing edge as well as the walls of a die stood the wear for drawing steel, brass, and other metals.

J. S. Pecker[8] asked whether chromium would deposit on aluminum; whether articles plated by chromium could be subjected to hard rubbing contacts; and whether steel parts previously case-hardened could be plated in a soft condition and used similarly to the case-hardened pieces. This latter was particularly important because on very many machine parts which had to be case-hardened to withstand wear and where the surfaces must be of certain true dimension, a final grinding operation was necessary. If such machine parts could be plated with chromium and would stand the usage that case-hardened parts had to, the process would certainly be an innovation in the machine trade.

Plating Dies with Chromium

Mr. Pecker also asked whether any difficulty had been experienced in the chromium getting to the very recesses of a die, and whether it was necessary to plate the entire die, both top and bottom, in order to get the plating on to the actual surface, or whether there was some means of protecting the other surfaces from becoming coated; and if the entire surface must be coated and some parts must be routed away, what were the best tools for routing. A man who was using chromium-plated plates for printing purposes had told him that they stood up six times as long as ordinary plates, but when he had occasion to route out a certain line around the actual printing surface, he had difficulty with the wear of his tools.

Other questions propounded by Mr. Pecker dealt with the adaptability of the average plating bath and apparatus for chromium plating, the plating of a small, deep hole, say, $^1/_8$ in. in diameter by $2^3/_4$ in. deep, and the uniformity of thickness of the plating where the parts being plated varied in thickness and in shape.

Dr. Blum, in closing the discussion, said that most of the questions asked dealt with specific applications or problems in the application of chromium for highly specialized uses for which he had no first-hand information.

As to the hardness of the coating, the chromium was found to be harder than any of the hardened steels that were tested. The fact that corrosion took place more readily in the center than around the edges on the plates exhibited was an illustration of the fact that the deposits were undoubtedly thicker on the edges than in the center, which was a result of the poor throwing power.

As to the effect of the spacing of the electrodes on the throwing power, he would say that it was an electrochemical function and was not necessarily affected by the spacing. On the other hand, the primary distribution was affected by the spacing, and, other things being equal, the deposits would be more uniform the further away the anodes were from the cathodes, because then the distances from the anodes to different parts of the cathode would be more nearly uniform. There was limit to this, however, for the wider the separation, the greater the voltage required to produce the required current density.

It had been found possible, after some experience, to get what seemed to be very adherent deposits of chromium both on steel and nickel surfaces, and in all the experience with thousands of plates at the Bureau of Engraving there had been no difficulty with the peeling of the chromium at any time.

The question as to whether chromium would be suitable for cutting and planing tools was partly answered by the statement in the paper that wherever the wear was due to abrasion, then the chromium would help, but if it was due to the bending or actual distortion of the base metal, then the chromium would likely contribute but little to the resisting of wear.

As to whether chromium could be plated on chromium, it could be done, but with greater difficulty than to deposit it on one of the other metals, and therefore with a gage it would be far more satisfactory to strip off the old chromium in hydrochloric acid—which would take less than five minutes—and then put on the required thickness, than to attempt to deposit chromium over a surface that was partly steel and partly chromium.

In regard to improving the surface of chromium by burnishing or tumbling, it was known that the porosity of a relatively soft metal like copper or even nickel was undoubtedly decreased by burnishing or even by ordinary buffing, because there was a flow of metal, but Dr. Blum doubted very much whether with any pressures used with burnishing there would be any appreciable flow of chromium to tend to actually fill up any holes.

There were very few authentic data on the coefficient expansion of chromium. Dr. Blum had found one reference which gave it as approximately 8×10^{-6}. Tests of a sample of electrodeposited chromium of more or less uncertain origin in one of the divisions of the Bureau roughly confirmed that value. The same determinations showed a sample of fused chromium—Goldschmidt chromium—to have a higher coefficient, namely, close to 10×10^{-6}.

As to the question of the thickness to which chromium could be deposited without peeling, there would be a greater tendency for peeling or cracking of a thick deposit than of a thin one. The Bureau had made deposits up to 0.005 in. in thickness, which, it was believed, was more than would be actually required for any purpose; but so far as appearances were concerned, obviously the thicker the deposit, the duller its surface would get. A thick deposit could not be kept as bright as a thin deposit under the same conditions.

As to producing polished surfaces by plating and stripping, this was very difficult to do because of the extreme brittleness of the chromium. If a film of chromium was stripped off another surface, it was likely to flake and curl. One of the best ways to get a strip of chromium was to deposit it on a more soluble metal like brass and simply dissolve off the brass.

Chromium Plating of Aluminum

Regarding chromium plating of aluminum, Dr. Blum said that the Bureau had not had occasion to investigate it, although it could be said on general principles that the plating of any metal on aluminum was much more difficult than plating on brass or the ferrous alloys. This was due to the fact that the aluminum tended to have a film, and in view of the fact that one of the methods now used for protecting aluminum was to put it in a chromic acid solution with or without a current to produce a film of oxide on the surface, it could be seen that there would be greater difficulty in chromium plating on aluminum than on any other metal.

The Bureau had not made any experiments in applying chromium to drawing dies, but had heard of some which would indicate it might be useful. The limitation there was its throwing power. In dealing with very fine wire, it was difficult, if not impossible, to get the chromium right down into the bore of the die, which was the place where the greatest wear might occur. On the other hand, if the chromium could be built up enough around the opening of the hole, it might be immaterial what size the hole was between the two ends provided the two ends of the hole kept their proper dimension.

As to the use of chromium for hard rubbing contacts, Dr. Blum could make no suggestion other than to cite the Bureau's experience with printing plates. There the hardest chromium deposit was the deposit produced at the highest current density short of actually burning. In other words, in making these printing plates experience showed that the best way was to run under those conditions that would give a very slight grayish—"frosty," as they called it—appearance on the corners where the current density was the highest, and depend on rubbing that off with a little emery, because then it would be known that the whole printing surface had the hardest surface of chromium.

Whether chromium could replace case-hardening or not depended on whether one was interested in surface wear or in resistance to deformation. Dr. Blum had been asked, for example, whether chromium would be a good thing to put on tire chains. While he knew of no actual experimental data on that point, he would certainly not consider that a very promising use for chromium, because any moderate thickness of chromium on the surface would almost certainly not prevent the actual tearing away of the metal that would occur under certain conditions of use of such an article.

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[8] Engineer, Machine & Tool Designing Co., Philadelphia, Pa. Assoc-Mem. A.S.M.E.

The question of whether dies could be plated depended altogether on the matter of throwing power. On printing plates, particularly intaglio plates, it made no difference whether the chromium went down into the lines or not, because all the lines did was to hold the ink. The wear was on the surface, and in this particular case the actual fact that the chromium did not go down into the lines improved the sharpness of the impression because the line was a little deeper after the chromium plating than it was before, and therefore, held the ink and gave a better impression.

As to the question of tools for routing chromium, the obvious thing was to do all machining beforehand. There was no use, for example, in making an electrotype and putting a hard surface on it and then deciding to cut out certain parts of that surface. All the routing, machining, and straightening should be done on the plate before the chromium was deposited.

As to whether parts could be protected against chromium plating, Dr. Blum said that there were a number of coatings, such as a bituminous paint, which would serve long enough for the plating operation to be carried out.

Regarding the bath and apparatus used, such as the tanks for chromium plating, they had found it most convenient to use ordinary stoneware tanks, though iron tanks were also used commercially. The fact that temperature regulation was required made it convenient to put a stoneware tank into a larger vessel in which the temperature of the water could be controlled by heating or cooling coils so as to keep the temperature of the bath approximately correct.

As to plating chromium all the way down into a hole $^1/_8$ in. in diameter and $2^3/_4$ in. deep, Dr. Blum did not believe that chromium or any other metal could be successfully deposited in a hole of those dimensions. It was barely possible that copper or zinc from the cyanide solutions might do down into such a hole, but it would be at least very difficult.

The uniformity of plating on gages and other articles, Dr. Blum said, was governed largely by the shape of the article and the distribution of the anodes. In the case of a cylinder, such as a gage, he thought that with a little experience, the plating could be kept so that there would be no variation greater than 25 per cent. In other words, in putting on 0.0002 in. of chromium there would not be more than 0.00005 in. variation between maximum and minimum thickness, which probably would be within the tolerance for most gages. In the case of a gage with a very small tolerance, the thing to do was to chromium-plate it and then lap it until the exact dimensions desired were obtained.

Technical Training in Woodworking—Its Status and Prospects

Reasons Why The Industry Has Hitherto Neglected Calling for Trained Technical Leadership—The Changed Present Status—School Development Along Wood-Utilization Lines

By THOMAS D. PERRY,[1] BOSTON, MASS.

Education, like everything else in this world, is a gradual evolutionary development, having had its origin in the dim past when parents trained their offspring, largely by instinct, to protect, feed, and clothe themselves. As education outgrew the home sphere it became a function of the church, and only quite recently has it become recognized as a public institution maintained at public expense, although private education has always been a considerable factor.

Training for an industrial profession or a vocation is perhaps the newest field of education, scarcely developed at all until the last fifty or sixty years, except through the apprenticeship method. It is not strange, therefore, that the present program of technical instruction is somewhat out of balance, overemphasized in some places and slighted in others.

Clergymen, lawyers, and doctors have been classified as belonging to the "learned" professions, but engineers seem never to have been included in such a distinguished group! Technological institutes began by training civil engineers, whose skill was needed to survey and plan our vast domain and to build railways and roads as the arteries of traffic. Then came the mechanical engineer, directing the conversion of natural resources into products for human use. Mechanical engineering soon came to be too broad a classification, and was separated into electrical, hydraulic, chemical, mining, and the like; still general classifications but tending toward segregation into industries. And the latest differentiation is subdividing further into the trained expert in railway transportation, the automotive engineer, the structural engineer, the highway engineer, the military engineer, the management engineer, and, last and perhaps least, the procurement engineer, a somewhat grandiloquent title for the purchasing agent! Such classifications and subdivisions may not always be comprehensive, but the tendency nevertheless is toward specialization in different trades and vocations. There is obvious danger in too much specialization, but perhaps there is an equivalent hazard to which the trade or vocation is exposed that does not have trained experts to maintain its progress and proficiency.

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More Complicated and Intricate Industrial Problems First to Feel Urgent Need of Technical Assistance

The more complicated and intricate industrial problems, requiring the most extensive resources, were the first to feel the urgent need of technical assistance. The problems were too involved and the expense too great to rely on rule-of-thumb methods. Industrial developments requiring many thousands or several millions of dollars of investment before beginning actual operations or securing profitable results, were forced to take skilled counsel, financial, legal, and technical, in order to be certain of gainful results. It is also true that large industries not only needed such technical advice, but the volume of product insured an appropriation for such service, even though it was a very small percentage of total costs. Hence we find such industries as the meat-packing trades, the electrical industries, the iron and steel trades, and the copper and brass associations, profitably using trained advisers, and obviously the demand for such men has prompted technical institutes to provide adequate engineering training.

There was a time when the conversion of ore into commercial iron and steel was highly individualized, and many communities had their "furnace." The names of many towns and localities bear mute evidence to this; in New Jersey, New York, Pennsylvania, and even in northern Michigan such designations are still found as "Oxford Furnace," "Bay Furnace," "Morgan's Furnace." Now these simple and modestly financed small plants have given place to the modern processes of the bessemer converter, the open hearth, and the like, and the units are in large aggregates and the capital requirements enormous. It is one of many evidences of the demand made for technical and research skill, and of the wonderful achievements thereby attained.

Production and Manufacturing Fields Regarded as Simple Will Be the Last to Demand Technical Assistance

This outline of the trend of the engineering requirements leads to the quite logical conclusion that the production and manufacturing fields that are regarded as simple have been and will be the last to demand technical assistance. It has been a popular impression, although decidedly aside from the whole truth, that it took little brains and exceedingly modest financial resources to become a

farmer or start a woodworking factory. It has perhaps been fortunate for the world that it was relatively easy to secure food and to build and equip a home, however modest and humble it might be, otherwise the human race might have long since become as extinct as the dodo.

Next to the fundamentals of food and clothing are the home and its equipment, houses, furniture, kitchen equipment, vehicles, musical instruments, and caskets. Wood has always been an essential to the human race, a necessity for intimate human requirements. In the early years of American development the man built the home and constructed the contents with his own hands, the woman cooked food and fashioned clothing. And some of the finest handiwork known has been handed down to us in fine needlework and durable, graceful antique furniture.

Modern conditions, however, have greatly changed the whole situation. Feeding and clothing a nation have become a vast complex of related industries, highly competitive and demanding the best of brains and brawn. Trained engineers are needed in every step of the program.

Within the last quarter-century the conversion of the tree into lumber, and the making of a board into a cabinet, have given rise to enormous sawmills and extensive furniture factories. The need has been growing for trained technicians in woodworking branches, but there has been a meager supply, usually recruited from other industries and acquiring their wood knowledge in the expensive school of experience.

Progressive Woodworkers Keenly Alive to Need for Trained Technical Leaders

The more progressive woodworkers are keenly alive to this need for trained technical leaders, and recognize the tremendous opportunities for improving the woodworking trades. The growing scarcity of lumber has enhanced its value. The inexcusable waste is staggering.

Woodworking is no longer the simple trade exemplified by the father doing his own woodwork, by the wayside carpenter and cabinet shop—once as flourishing as the country blacksmith—by the novelty works, and wood-turning shops. These are fast fading from the modern picture, and in their place we find the sawmill producing carloads of lumber daily, the many sash-and-door factories in the upper Mississippi Valley, the box-shook plants in New England, the grouping of furniture manufacturers at Grand Rapids, Jamestown, High Point, Evansville, Gardner, and Rockford, as well as such consolidations as the National Casket Company with many merged factories, and the many factories converting hardwood into flooring.

The demand for trained woodworking executives has grown rapidly, and our schools and colleges are not yet meeting the needs. Without making the slightest claim to being an educational expert, it is still possible for the author to suggest ways in which our educational system should meet this growing need of woodworkers, and achieve the same marked success that our technical institutes have made in the training of executives in other lines.

Trained woodworkers fall into two classes, the artisan and hand craft worker, who constitutes the rank and file of the woodworking army, and the trained executive, who leads the army to new industrial victories.

Trade and vocational schools are doing much to supply the need for the former, but in rather an indifferent way. Woodwork seems simple to the pupil; it has little of allurement, is usually made too much of a necessity, and not enough of interest and attraction is woven into the courses of instruction. According to excellent authorities, woodwork is yielding its preëminent place in the manual-arts public school to the more intriguing subjects of auto mechanics, radio, and the like.

The concern of engineers, however, is more in the realm of training leaders for the industry. What are our technical schools, universities, and colleges doing to offer opportunities for the training in woodwork, the equivalent of which can be easily found in metal work, electricity, transportation, road making, chemistry, etc.? There is no answer to this question, or at least none at all adequate.

On the other side of the picture we find that technical schools are offering courses for which students make a demand, courses that will enlist support and draw attendance. A number of large industries are known to be watching the output of our better technical institutes, and usually absorb from six to twelve graduates each year. Students are naturally looking for jobs, and schools do not wish to offer courses from which graduates have difficulty in securing employment.

Largest Success of Woodworking Industries Waiting on Availability of Trained Executives

Somewhere in this cycle of growing demand for woodworking engineers of executive types and the reluctance of technical institutes to offer courses in any specialized trade subject until the demand is obvious, there must be a change. The woodworking industries are not going to succeed in a big way until trained executives are available in reasonable numbers, and the schools are not performing their duty unless they supply training according to industrial and commercial demands.

It is at this point that professional organizations like The American Society of Mechanical Engineers and its many sister organizations can be of great value in welding together these two requirements of industrial need and educational expansion. The first step—and considerable progress has already been made along this line by the Wood Industries Division—is to develop programs and literature emphasizing the need and to lay evidence before the schools that a new opportunity is available, and should be improved.

The next step is to work directly with the proper authorities of our leading technical institutes, persuading them to offer options along the lines of woodwork utilization, to accept theses on such subjects, and to encourage students to enter lines of activity in which the eventual opportunities are so great, even though the immediate openings may not be so alluring.

This is a chance for intimate personal contact and persuasion with our own schools and universities, where a proper presentation of facts will surely secure respectful attention. School authorities are always on the lookout for opportunities for progressive leadership.

School Development Along Wood-Utilization Lines

It would not be fair to close without outlining some of the school developments along wood-utilization lines, few though they be, considering the magnitude of the subject. There are a number of forestry schools, training very splendidly for forest service, or the growing and protection of forest life—an essential part of woodworking, but these forestry schools do little or nothing with the utilization of wood after the tree has reached marketable size. This forestry training is most essential and commendable, since it does much to insure a supply of wood for the future. However, the conversion of wood into final product at the present time is attended with enormous losses. It may be said without fear of contradiction that of the potential wood in the forest tree, only one-half ever becomes utilizable lumber; and of the lumber that goes into our factories, only one-half ever reaches the finished product. In other words, seventy-five per cent of the wood is lost in manufacturing processes. If five per cent of this waste could be salvaged by better-trained executives, it would amount to our annual requirements every fifty years. No process of conservation will be as immediate in its effect, nor as effective in continuing the supply of virgin forest trees.

New York and Pennsylvania have developed courses in state institutions directed toward utilization by coöperation with state industries. Wisconsin has its Forest Products Laboratory, maintained jointly by the state and federal governments, emphasizing both forestation and utilization. So far its work seems to have been more of a laboratory research character than instructional. The retail lumber dealers of Ohio have sponsored a course in "Lumber" at Antioch College, but this is more business administration than engineering technique. The Stout Institute at Menominee and the Bradley Polytechnic Institute at Peoria offer courses which lean rather strongly toward the manual arts, and do not specialize on college-grade work. But the aggregate opportunity for the student who would become a woodworking executive is exceedingly small.

Perhaps a word ought to be said about the magnitude of the woodworking industries as a whole. The 1923 report of the Department of Commerce (latest available) gives the following total of manufactured products.

Metal Groups:		
Crude iron and steel	$4,161,938,000	
Manufactured iron and steel	2,686,903,000	
Machinery (excl. transportation)	4,727,818,000	
Other metals and metal products	2,634,041,000	$14,190,690,000
Food and Kindred Products		9,524,051,000
Transportation Groups:		
Equipment (motor and railway)	5,333,480,000	
Railroad Repair Shops	1,520,093,000	6,853,573,000
Wood Groups:		
Lumber and Allied Products	3,633,084,000	
Musical Instruments	282,531,000	3,915,585,000

Textiles and Their Products	9,487,184,000
Chemicals and Allied Products	5,706,866,000
Paper and Printing	3,769,985,000
Leather and Its Manufactures	1,880,085,000
Stone, Clay, and Glass Products	1,538,571,000
Tobacco Manufactures	1,044,192,000
Rubber Products	958,519,000
Miscellaneous Industries	1,686,718,000
Total Value of Manufactured Products for 1923	$60,555,998,000

Woodwork ranks sixth in our magnificent manufacturing roster, and certainly needs vastly more attention than it receives from schools, colleges, and technical institutes.

The Place of the Engineer in the Woodworking Industries

A Discussion of the Immediate Need of These Industries for the Application of Engineering Principles and Practice in the Elimination of Waste, the Utilization of Little Used or Little Known Species of Wood, and in Improving the Precision of Woodworking Machinery

By WILLIAM BRAID WHITE,[1] CHICAGO, ILL.

IN ORDER to make plain the aim of this paper, it is probably best to begin by answering the question, "What is an engineer?" And the answer is that by the name "engineer" we today describe one who plans and directs mechanical processes and operations. The engineer is not one who merely carries out, but one who directs; that is to say, who designs, who plans, and who supervises. These functions of his can be executed aright only if and when he comes to his task grounded in the physical and mechanical principles of machine design and of mechanical production. More and more all processes of manufacture tend to become purely mechanical; that is to say, more nearly automatic. The ideal presupposed in the humorist's dream, of a factory which consists of a huge machine taking in raw materials at one end and giving out at the other complete automobiles, locomotives, pianos, or sewing machines, tends slowly but steadily toward realization.

Naturally the susceptibility of any industrial process of manufacture to mechanical treatment of this kind, where the ideal is purely automatic and human skill may almost stop at the design and construction of the machines which are to do the work, depends in very great measure upon the nature of the raw material which is to be dealt with. The metals, iron, steel and so on, are in a much better condition than is, for instance, wood when it is a question of mechanical treatment. For wood is in one way the most, and in another the least, dependable of raw materials. On the one hand, it is easy to handle, comes in a very great variety of species with a great and useful range of diverse physical and mechanical properties, is durable, beautiful to look at, and possessed of considerable strength. On the other hand, no two pieces of wood of the same species can be regarded as absolutely identical in respect of physical and mechanical properties, while the influence upon all species of atmospheric and hygroscopic conditions is very great and continually causes changes in dimensions and moisture content. It is thus impossible to deal with wood as a raw material in that sure and simple manner which is taken for granted when the material is steel or iron. A piece of wood which is just so long and so wide one day, may be perceptibly longer and wider the next day, merely owing to its absorbing moisture from the atmosphere; nor is it possible to control this variation within the close limits to which workers in metals are accustomed.

All this of course is well known to engineers, but it is said here in order that what follows may be placed in stronger relief. For it is evident that the application of engineering methods to woodworking involves difficulties much greater than might at first be suspected. And this in itself explains why these industries have for the most part lagged behind the others in the adoption of such principles.

Waste and Inaccuracy Once Characterizing Woodworkers No Longer to Be Tolerated

Nevertheless, the woodworking industries have gradually but inevitably been coming to see that despite the peculiar nature of their raw material, advancing prices and diminishing supplies can no longer be treated with indifference. The waste and inaccuracy which have alike characterized the operations of woodworkers can no longer be tolerated. Engineering methods, at least comparable with those which we have come to take for granted in the machine shop, must be worked out and adopted, as rapidly as conditions will allow. The mechanical engineer, therefore, the trained practical scientific man who has learned to regard the micrometer gage and the indicator card as familiar tools, is coming into his own in the woodworking industries.

In them he finds conditions both strange and fascinating. Wood is the universal material even more nearly than is steel. Wood is still the only universal raw material available to the semicivilized inhabitants of the earth, and even the most civilized of western nations still finds it so valuable and so convenient that it will complacently face the prospect of a complete timber famine within the space of a generation, if it can only obtain a full supply for today.

It is indeed this very appetite which is compelling every thinking man and woman on the North American continent to realize the absolute necessity of some change in the attitude which has for so long been taken toward the supply and the consumption of wood. When the land first was occupied and the long process of subduing it to man's wants was begun, forests were actually an obstacle to the spread of civilization. They had to be cut down before civilized man could live on the land. But the process of destruction has been so rapid that living men still remember the day when states now bare of timber were almost wholly virgin forest. What was once felt to be an inexhaustible natural resource has been manifestly failing before our eyes; and today the question of applying methods of economy to its cutting, its manipulation as primary or as secondary material, and its use for a thousand and one various requirements, is no longer merely of academic interest. It is now a practical question. The woodworking industries, from lumber manufacture through sash and door construction and building work to the highly organized and complex processes of cabinet making, pianoforte construction, organ building, and so on, are today calling for men to work out methods of economy. The call for the mechanical engineer is therefore daily becoming more insistent. The old and more or less happy-go-lucky methods which were quite satisfactory as long as the supply of every

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kind of wood was abundant and cheap, are seen no longer to suffice. To sum up, the immediate needs of the woodworking industries in respect of engineering methods and principles, are substantially as follows:

Immediate Needs of Woodworking Industries in Respect of Engineering Methods and Principles

First, the study of the physical and mechanical properties of wood has become during recent years one of the most interesting and practical of the industrial sciences. Woods vary extraordinarily in their physical properties, and in their availability for industrial use. There are woods like some of the maples which when quarter-sawed show a hardness of surface and a resistance to tensile and shear strains that put them, especially when worked up into plywood, quite in the metals class. There are other woods so soft that they cut almost like cheese, but at the same time are extremely useful for bearing certain kinds of strain, especially when protected by veneers of harder wood. And there are a thousand varieties in between these extremes. The study of these on engineering lines has become vastly important, and a large institution devoted to this and similar ends now exists in the shape of the Forest Products Laboratory at Madison, Wisconsin, which is maintained by the Forestry Service of the United States in coöperation with the University of Wisconsin. It would be well if every member of the A.S.M.E. might have the opportunity and the inclination to visit this remarkable laboratory. Here he would find going on every day at the hands of a staff of highly trained chemists and mechanical engineers practical research in the physics, the chemistry, and the industrial application of every possible species of timber. He would find that industries are submitting problems to this laboratory of the most practical kind, and getting answers equally practical. He would learn, for instance, that the practices of the wooden box, crate, and container industry have been completely revolutionized as a result of researches made by the laboratory in coöperation with that industry. He would find that contemporary knowledge of glue, of gluing methods, of plywood construction, of waterproofing, of the strength and resisting powers of various species of woods, and of a thousand more industrially important facts concerning the use of the great universal raw material, has taken its origin in the Forest Products Laboratory. Partly on its own initiative, partly in coöperation with industries, this remarkable institution is every day showing the wonderful possibilities of conservation and of economy in using wood, which scientific methods of investigation, undertaken by practical scientific men, can bring to light. The mechanical engineer who looks toward the woodworking industries should first cast his eyes northward to the city of Madison. There he will find a fountain and source of scientific woodworking knowledge. And there are others. Working to the same end are such admirable institutions as the great Forestry School at Yale University, the school at Syracuse University, and the Mellon Institute. There is, however, ample room for much greater development in this way, and the call for trained engineers capable of doing research work is certain to become more insistent year by year.

The scientific utilization of wood products begins with the selection of species. It is here that the wood technologist most plainly shows to the wood-using industries his practical value. There is an immense amount of useful and practical work to be done in the way of investigating the feasibility of employing little used and little known species for industrial purposes now monopolized by other species rapidly deteriorating in quality and in certainty of supply, while steadily appreciating in price.

Economic Possibilities in the Use of Dimension Stock—Seasoning

Secondly, a great field of useful work opens before the engineer in bringing about a better understanding by the woodworking industries of the possibilities of what is called "dimension stock;" that is to say, lumber cut in certain standard dimensions, and used mainly for the interior work of framing and for similar utility purposes. Vast economies in the consumption of wood may undoubtedly be found in the wise use of dimension stock, but the subject is still so new that an immense amount of investigation and replanning is needed to make it appeal to woodworking executives. Here is a large field of work for the trained mechanical engineer, one sure to become larger, and constituting a veritable approach to the precision methods of the machine shop.

Thirdly, wood must be seasoned before it can be used for any of the finer purposes, such as furniture, musical instruments, the interior trim of houses, automobile bodies, etc. The extraordinary longevity of ancient furniture, buildings, and musical instruments constitutes certain evidence that the old craftsmen, in their slow, painstaking way, had mastered the art of wood seasoning. Modern industrial methods demand speed and demand it insistently. Unfortunately, however, speed has too often been gained at the expense of thorough drying, and now it has become necessary to organize a science of wood seasoning, as it may be called. The work of the Forest Products Laboratory and of such independent experts as Thomas D. Perry of Boston has brought this science to a high degree of perfection and has opened up for the engineer another new woodworking field. Seasoning is as important a part of woodworking as cutting the log or gluing one piece to another. In fact, without scientific seasoning methods, woodworking becomes almost disastrously uncertain and unreliable. Yet the development of the technique along scientific and engineering lines is still new and still in the formative stage. Here, then, is still another field of opportunity.

Gluing—Plywood

Fourthly, the whole vast field of gluing operations, including that of plywood construction, demands the closest attention from the engineer. Much has been learned about plywood since the epoch of the Great War. We know now that this artificial construction is endowed with a shear-resisting strength far exceeding that of solid wood. We know that with modern methods of gluing, plywood is waterproof and virtually immortal. But the field of the application of plywood is as yet hardly at the beginning of its exploitation, and there is an immense amount of engineering work to be done yet in developing its wider use. This is precision work and scientific work demanding talents of a high order.

Opportunities in the Woodworking-Machinery Field

Fifthly, there is the great field of engineering methods for the design, construction, and use of woodworking machinery. It is this which will perhaps appeal more immediately than any other to the imagination of the mechanical engineer. Woodworking machinery is today approaching the degree of specialization, of precision in design, of precision in cut and finish, which we are accustomed to find in the machine shop. Such a fundamental investigation as the Wood Industries Division of the A.S.M.E. is conducting into the behavior and possible standardization of saws and cutting knives merely adumbrates the vast possibilities of engineering research in this field. Like so much else in the oldest of industrial processes, woodworking, this too is new. The mechanical engineer may bring to the woodworking industries the results of his long experience in the accepted machinery fields, whereby he may be able to work out by degrees standardized machine parts, better machinery for handling materials, and more efficient and economical systems of furnishing power to machines, all powerful influences in eliminating waste and in reducing overhead charges.

On this matter of machine design and construction it may be said most positively that a great quantity of accurate data is needed as to speeds and feed rates of machines and tools. Few of such data exist, and these are partly out of date.

Sixthly, certain very highly organized and specialized woodworking industries, like piano construction, organ building, and musical-instrument manufacture generally, call most insistently for the application of scientific principles and engineering methods. The musical-instrument field constantly develops in size and in specialization; but it is unfortunately only too true that in no industries of like magnitude can one find such excessive conservatism. The value of the pianofortes made each year in the United States alone exceeds one hundred millions of dollars; and if improvement both mechanical and musical were the rule, it is extremely probable that the total would be much greater. There is a place, a very large place, in the music industries for the engineer who can combine mechanical training with a thorough knowledge of acoustics.

In sum, then, it appears that the opportunities for the mechanical

engineer in the woodworking industries are almost limitless. They are limited, indeed, just by the interest and ambition of those engineers who may be attracted to them. Whatever problems the mechanical engineer has had to solve in the metal-working industries may be found paralleled in the woodworking field. If the inquiring engineer asks why the woodworking industries have lagged so far behind in the application of precision methods, the answer mainly is that until very recently there has been no compelling financial incentive to economy. Wood has been a cheap and an apparently inexhaustible natural resource. Today it is no longer anything of the sort. Necessity is accomplishing what neither good citizenship nor good engineering sense could of itself accomplish. The woodworking industries are become engineering industries. The day rapidly approaches when the precision of the machine shop shall be added to the skill of the craftsman, so that the beauty and the charm of fine wood, finely designed, finely fashioned, and finely finished, may be realized to an extent not now more than dimly foreseen.

Mechanical Loading and Coal-Mine Management

By H. F. McCULLOUGH,[1] FAIRMONT, W. VA.

WHILE mechanical loading and conveying equipment has been available for the coal-mining industry for more than 20 years, mechanical loading of coal cannot yet be said to be economically successful, except in a few special cases.

There are two general opinions as to why better results have not been obtained with mechanical loading and conveying equipment. Equipment manufacturers say that coal-mine operators have generally failed to establish and maintain the conditions required for success, while according to the latter the equipment will not cope economically enough with their conditions.

When one sees the advantages of the introduction of coal cutters and electric haulage locomotives, one naturally thinks that a satisfactory mechanical substitute for the man with the shovel should likewise increase productive efficiency. It is true that the mechanization of coal loading makes possible the mechanical handling of all the major tangible factors connected with the production of coal, but these tangible factors are not the only ones which condition and control production.

While fairly effective mechanical loading and conveying equipment is and has for some time been available, yet except in a comparatively few instances mechanical loading has not been made an economic success, to say nothing of having obtained the results which might rightly be expected from a consideration of the known capabilities of the equipment itself. Our innate faith in the efficacy of machinery seems rather generally to have obscured the existence or minimized our estimation of the importance and influence of the intangible factors which condition and control productive efficiency at least to as great an extent as the mechanical equipment employed.

The increased efficiency obtained by the other productive industries has been the result, first, of more effective management; second, of specialization of work; and third, of increased use of machinery. The provision of more mechanical equipment alone does very little in the way of increased productive efficiency.

The Need for Coördinated Management

The need for coördinated management is evident from even a casual inspection of almost any coal-mining operation.

The sooner mine operators disillusion themselves as to the possibility of any mechanism materially increasing the productive efficiency of coal mining, and the sooner they buckle down to systematic planning and coördination of operations, the sooner will productive efficiency be materially increased.

Perhaps the most efficient coal-mining operations today are those relatively few hand-loading operations in which practically each different kind of work has been delegated to a specialist, leaving to the miner only the actual loading of the coal into mine cars. Thus the coal-mining industry has already made considerable progress in mechanization, and some progress in specialization. Specialization of coal cutting and drilling came about through the introduction of cutting and drilling machines. Appreciation of the advantages gained through the specialization of these operations led to extensions of the idea, so that there is now in some operations specialized timbering, track laying, shot firing, etc.

In non-specialized and non-mechanized coal mining where each miner performs practically every operation up to the point of placing empty and removing loaded mine cars from the room neck, the miner is paid in accordance with what he produces. The miners, being paid in accordance with the tonnage produced, bear the direct costs of part-time operations and such delays as may occur. From the standpoint of mine management, nothing could be simpler.

Loading the Pivotal Operation in Coal Mining

Loading is the pivotal operation in the mining of coal. To load coal, empty mine cars must be brought up and loaded ones taken away when and as required. Loading can only be as rapid and continuous as the supply of mine cars will permit. Hence the two principal factors in the mining of coal, loading and transportation, are linked together and the overall efficiency is directly determined by the haulage and loading arrangements and by the degree to which these function together. Until adequate trackage is provided for mechanical loading and conveying equipment, and until coördinated operation is established through specialized planning, scheduling, and control, nothing but inefficiency can be expected, irrespective of what equipment is provided.

The arrangements necessary for adequate transportation service can easily be provided, and in some instances considerable progress along these lines has already been made. Hence, the real remaining problem appears to be that of coördination of operations.

A representative of a loading-machine manufacturer recently interested a coal-mine operator in mechanical loading to the point of being ready to purchase some equipment. The operator then asked casually what he should do to get ready for the loading machines. The representative suggested that his mining plan be modified so as to call for the driving only of narrow work in the first or advance working; that rooms be driven comparatively narrow, and on wide centers, so that only a small proportion of the coal be extracted on first mining; and that the major part of the coal be recovered by pillaring on the second or retreat working; that all mining, both advance working and pillaring, be done systematically and according to plan; that no more territory be opened up than was necessary for the maintenance of the proposed production; that track of suitable weight and character be laid, conditioned, and maintained; that suitable and adequate side tracks, mine cars, and haulage equipment be provided and maintained in suitable condition; that all these things be planned and provided for in advance; and that coördinated operation be obtained through systematic planning, scheduling, and control of operations. The operator exclaimed that if he did all these things he would have a world-beating mine without having to use mechanical loaders.

This operator's conclusion may have been correct, but the fact remains that these things must be done before mechanical loading can be made anything more than a mediocre or doubtful success, irrespective of how good the natural conditions or labor situation may be.

It may therefore be true that the most important immediate benefit to be obtained from mechanical loading and conveying equipment will be that, before installing them, operators will be compelled to improve mining practices in order to justify the use of the new equipment.

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Extracts from a paper presented at a joint meeting of the Chicago Sections of the A.I.M.E. and A.S.M.E., Chicago, January 20, 1927. To be published later in full by the A.I.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS (See also Internal-Combustion Engineering: Effect of Reduced Intake-Air Pressure and of Hydrogen on the Performance of a Solid-Injection Oil Engine; The Etchegoin-Causan Engine)

Flying Clubs in England

THE following passage is quoted verbatim from an editorial entitled Progress in 1926:

"In civil aviation there has been quite a great deal of progress, and it seems to have sprung up quite suddenly. In spite of the Gliding Meeting in 1922 and the flying of light airplanes in various competitions in 1923, 1924, 1925, and 1926, there has been astonishingly little interest in private flying until this past year. A few enthusiasts have owned machines. And there have been the usual articles, and references in speeches, by people who know nothing whatever about aviation, about the great flying era of the future in which everybody will keep airplanes in their own back yards and apparently fly them off tennis courts, or off the public road. But there has been precious little general interest in the subject until this year.

"Whether it was that the psychological momentum caused by the growing interest in flying among all classes of people influenced the Air Ministry, or whether it was that the Air Ministry received direct inspiration from God in the interests of the British nation, one would not pretend even to guess. But there is no doubt that the Air Ministry did start the flying clubs at precisely the right moment. And as the result of the club movement all sorts of people are beginning to take an active interest in flying who would otherwise never have had a chance.

"We must not forget that the way for the success of the flying clubs has actually been paved by all the joy-ride flying done by the Berkshire Aviation Tours and the Surrey Flying Services, and the Cornwall Aviation Company and sundry minor concerns who have carried hundreds of thousands of passengers with remarkable freedom from accident. But anyhow the year 1926 does mark the climax when the mere joy riders have begun to become practical aviators.

"The Air Ministry's excuse, or perhaps one should say the excuse of the official apologists of the Air Ministry, for expending John Citizen's money on buying airplanes for and giving cash subsidies to the flying clubs, is that the clubs may be regarded as a source of supply for future pilots for the Royal Air Force. Personally, one regards that excuse as pure bunkum.

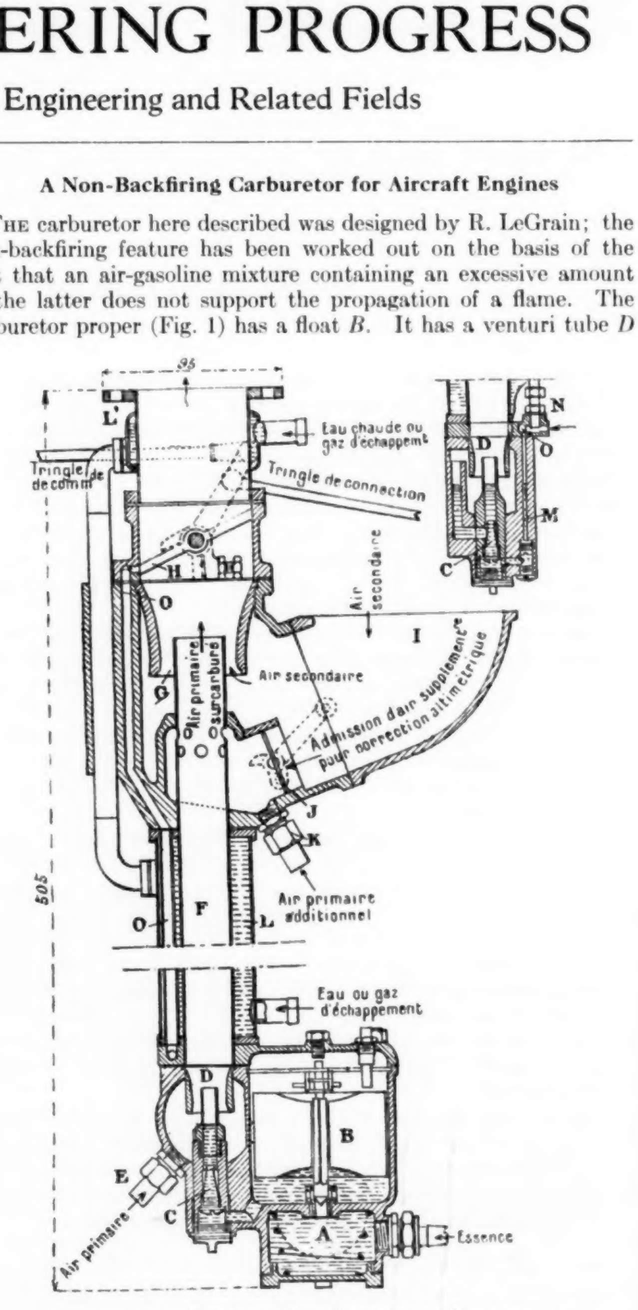
"One believes that only a very small percentage of the people trained to fly by the flying clubs would be useful as pilots in time of war. Probably most of them would never pass the R.A.F. Medical Boards, and probably a lot more of them would have no ambition to fly in the face of the enemy at all, even though they have no objection to flying in the face of Providence, as some of them do at present—judging by their maneuvers in the air.

"The real usefulness of the flying clubs is to form little centers of aeronautical thought and action all over the country, which by increasing the psychological moment among the people help to make the nation air-minded, according to the gospel of St. Hoare. In fact, one regards the flying clubs very much more as little bands of apostles among the heathen than as serious sources of supply for the R.A.F.

"Certainly in the future, as flying becomes a national sport, and as the lad of the village take to keeping an airplane instead of a speed car, they will be potential sources for the supply of pilots, but they are not at present. They are in fact something far more important than that. And 1926 deserves to go down to history as the year which saw the rise of the club movement." (*The Aeroplane*, vol. 32, no. 2, Jan. 12, 1927, p. 29, entire editorial, pp. 29–30 and 32, *g*)

A Non-Backfiring Carburetor for Aircraft Engines

THE carburetor here described was designed by R. LeGrain; the non-backfiring feature has been worked out on the basis of the fact that an air-gasoline mixture containing an excessive amount of the latter does not support the propagation of a flame. The carburetor proper (Fig. 1) has a float B. It has a venturi tube D



FIGS. 1 AND 2 LEGRAIN NON-BACKFIRING CARBURETOR

(*Tringle de commande* = driving rod; *tringle de connection* = connecting rod; *eau chaude ou gaz d'échappement* = hot water or exhaust gas; *air primaire surcarburé* = primary air carrying an over-rich mixture; *air secondaire* = secondary air; *admission d'air supplementaire pour correction altimétrique* = admission of additional air for altimetric correction; *essence* = gasoline.)

and a needle C regulating automatically the supply of gasoline in accordance with the work of the engine. The primary air entering at E is over-rich and constitutes a non-explosive mixture conducted to a secondary mixing chamber G which it reaches by a vaporizer tube F heated by cooling water or exhaust gas circulating through a double jacket L. In this secondary mixing chamber shaped as a large venturi the secondary air coming from I is added to the primary over-rich air to form a normal mixture, the admission of which to the engine is regulated by the butterfly valve H. A supplementary reheater L' insures complete vaporization of droplets of gasoline held in suspension in the air. When working at low altitudes the operation of the device is exactly as has been described above, but at high altitudes, in rarefied air, the pilot may effect a correction for altitude by opening to a suitable extent the butterfly valve J which admits extra secondary air. The admission of this additional air toward the top of the tube F de-

creases the richness of the mixture not only because it introduces the air itself, but also because it reduces to a certain extent the suction above the needle C, which in its turn decreases the flow of gasoline.

When the engine speed is reduced with the butterfly valve H controlling the admission of mixture practically closed, a very strong decrease of pressure is produced in the passages O. The gasoline coming in through an auxiliary slow-down needle M (Fig. 2, in upper right-hand corner) forms a very rich mixture with the air admitted through the orifice N which may be properly regulated. This mixture gains in temperature as it passes through conduit O, enclosed as it is in a hot-water jacket L; the mixture then flows toward the suction pipe near the butterfly valve H, and forms with the small quantity of air passing around that valve a detonating mixture suitable for running the engine at slow speed.

If, however, the normal mixture admitted to the engine cylinder should ignite prematurely, as, for example, from gases of combustion in residue in the explosion chambers, then the backfire may safely pass into the second diffuser G. But the flame goes out in the fairly long tube F which contains only an over-rich and therefore non-inflammable mixture, and hence the flame cannot reach the float chamber. Apart from the advantage offered by way of security from fire, the principle of two-stage carburetion helps to insure a regularity and homogeneity of the final mixture, and also, as stated above, permits adjusting the action of the carburetor to altitude.

It is claimed that on the motors on which this carburetor was tested a slight increase of power output and speed was noticed, accompanied by a notable diminution of gasoline consumption. The original article shows how this carburetor is installed on a 480-hp. Renault motor. (*Le Génie Civil*, vol. 89, no. 26, Dec. 25, 1926, p. 598, 3 figs., *dA*)

AIR ENGINEERING

Refrigerating as Applied to Air Conditioning

The author, who is chief mechanical engineer of the Commonwealth Works Department, Melbourne, Australia, describes Australian practice in the cooling of building interiors, which has apparently advanced there further than in the United States.

In Melbourne, the author states, the temperature ranges from 27 to 111 deg. fahr. and the relative humidity from 20 to 100 per cent, with tap water approximating 72 deg. fahr. in summer and 45 to 50 deg. fahr. in winter. With no prospect of obtaining colder water from underground sources, air cooling by water evaporation can only be looked for during the limited periods of high temperature and low humidity.

For automatic telephone exchanges it is stipulated that the relative humidity shall not exceed 70 per cent and that the air shall be clean. With a view to economy in installation and operating costs, attempts were made to obtain these conditions by means of air washing and heating. The buildings were constructed to minimize the chances of untreated dust-laden air entering the switch room.

Under normal working conditions in automatic exchanges, about 8000 cu. ft. of air space is available for each employee. This was considered large enough to warrant not more than one change of air per hour, and that was the provision made for the first exchanges equipped with ventilating plants, including air washers. The heating was by direct water radiation. Provision was also made for vacuum cleaning and for compressed-air dusting.

The author describes the typical arrangement of a plant designed to meet these conditions, where air cooling was effected by passing the air through a water spray. With this plan, however, the humidity could be maintained within the required limits only at temperatures too high for comfort, and this experience indicated the necessity for more frequent changes of air and the introduction of means for reducing its temperature. A plant with artificial refrigeration was therefore designed, and in this connection consideration was given to the American air-conditioning practice in which Baudelot coils are generally used. On account of the risk of carrying ammonia gas through to the telephone switch room (the plant was installed in a telephone-exchange building), it was decided to submerge the ammonia coils completely.

The original article next describes the layout for the Collingwood telephone exchange and gives a chart showing the results of the operation of this plant. Another hygrometric chart given in the original article has been adopted from various American and Indian sources to cover range of atmospheric conditions usually met with throughout the Commonwealth. Further, a plant recently designed for a telephone exchange in South Brisbane is also described. Here experiments have shown that some advantage accrues from increasing the air-cooler curtain for condenser water and the condenser surface. Charts showing the relation between spray temperature and refrigerating effect with and without refrigeration, appear to indicate that where refrigeration is resorted to, the actual cooling effect is very much in excess of the rated; considerable saving in refrigeration can be obtained by maintaining the spray temperature as high as possible. In fact, from the curve referred to here, it is seen that with the spray temperature of 45 deg., three times the cooling is effected compared with spray water at 35 deg. fahr. The experience with these plants has led to the adoption of a number of minor changes in the installation designed for ventilating and air-conditioning the two debating chambers and library of the Commonwealth Parliament House at Canberra. (Paper by A. Lewis before the Victorian Institute of Refrigeration, abstracted through the *Heating and Ventilating Magazine*, vol. 24, no. 1, Jan., 1927, pp. 80–86, 8 figs., *dce*)

AIR MACHINERY (See Railroad Engineering: Vacuum-Brake Tests on Long Freight Trains)

ELECTRICAL ENGINEERING (See Measuring Apparatus: The Klydonograph Surge Recorder)

FUELS AND FIRING

The Residual and Extinctive Atmospheres of Flames

When a jet of combustible gas or vapor is allowed to burn in a closed vessel, the flame gradually alters in character as the oxygen diminishes, and finally goes out. The atmosphere remaining is usually termed "the residual atmosphere" and contains, besides a proportion of unconsumed oxygen, the products of combustion and the original nitrogen.

On the other hand, a mixture of oxygen and some "inert" gas, such as nitrogen or carbon dioxide, can be prepared which is just unable to support the burning of a jet of combustible gas introduced into it. Such an atmosphere has usually been referred to as the "extinctive atmosphere."

The oxygen percentages of the residual and extinctive atmospheres do not necessarily coincide, and the results are also considerably influenced by the method of determination employed. The oxygen content of such atmospheres varies also with different gases. The author reports several previous investigations and discusses the reasons for these variations.

The author finds that, other conditions being constant, the production of inflammable mixtures is facilitated by a high rate of diffusion and low-oxygen requirements. Combustion takes place readily—(1) If the gas is of a high order of inflammability as evidenced by the relative speeds of flame propagation in its range of mixtures with air; (2) if the gas has a wide range between its limits of inflammability in air at ordinary temperatures and pressure, and (3) if the products of combustion have a lower specific heat than the diluent gas or gases in the original atmosphere. It is probable for these reasons that hydrogen is able to burn in atmospheres containing less oxygen than such gases, as methane or moist carbon dioxide. The author discusses next to what extent the compositions of atmospheres are likely to be affected by the methods adopted for their production. In dealing in particular with extinctive atmospheres, he says that the flame burning under certain favorable conditions concerning size of orifice, speed of gas stream, and speed of current of atmosphere, requires a smaller oxygen concentration than when burning under less favorable conditions. Furthermore, an atmosphere which may extinguish a flame is also capable of forming an explosive mixture. (T. F. E. Rhead in *Fuel in Science and Practice*, vol. 6, no. 1, Jan., 1927, pp. 37–40, *ep*)

The Use of Slow-Combustion Fuels in Explosion-Type Internal-Combustion Engines

In a previous paper (June, 1924) the author showed that it was possible to burn kerosene in an ordinary internal-combustion engine. In the course of the investigation which led to the writing of that paper, he observed explosive phenomena produced by a mixture of air and kerosene vapor. Later he found that it was possible to burn heavy fuels by associating them with lighter fuels acting as atomizers. He then became interested in the question whether the reverse was possible, i.e., whether it was possible, by decreasing in a carburant the proportion of heavy products, to decrease the proportion of the lighter products without interfering with the combustion.

The essential quality of a fuel employed in an explosion engine is its homogeneity. It is because of this that specifications for aviation engines demand gasolines that will distil between 60 and 140 deg. cent., which means gasolines which are not only homogeneous but extremely volatile. These specifications at first glance appear to be logical, and yet in the opinion of the author they are basically wrong because of the fact that all endurance tests on which the working out of the specifications was based were carried out at sea level, while in actual practice an aviation engine has to run at all kinds of altitudes.

Now, one of the properties which contribute to the successful formation of a carbureted mixture and its homogeneity is the vapor tension of the fuel with respect to air. In the case of an aviation motor the vapor tension of the fuel remains constant, while the atmospheric pressure decreases with altitude. This led the author to the hypothesis that it might be possible to produce a fuel having the same characteristics of homogeneity as aviation gasoline, fluidity comparable to that of the latter, and a vapor tension equal to α per cent of the tension of aviation-gasoline vapor. Such a fuel in an aviation motor would produce at an altitude where the atmospheric pressure was α per cent of the pressure at sea level, conditions of operation comparable to those produced by aviation gasoline at sea level. With this in view the author turned his attention to the employment in an aviation engine of a commercial product of petroleum refining called "white spirit," a product remarkable for its homogeneity and distilling between 130 and 180 deg. cent. (266 to 356 deg. fahr.).

After trying the fuel in an automobile engine, the author ran a bench test on an aircraft motor of 180 hp. without any changes in either the motor or the carburetor. After proper adjustments the engine was installed on an airplane, and in the very first test Engineer Ceccaldi made a flight of half an hour at an altitude of 3000 meters (9842 ft.) with the motor running well at all outputs and slowing down in a satisfactory manner. It was found, in accordance with the above hypothesis, that the revolutions at sea level were below those obtained with gasoline (1480 instead of 1530), but exceeded the latter at 3000 ft. (1700 as compared with 1650).

The rise from the ground was made on gasoline and the landing on white spirit. The most important advantage this fuel possesses is that it does not develop any inflammable vapors until a temperature of 30 deg. cent. (86 deg. fahr.) is reached.

The question which the author considers next is the limit of the proportion of heavy oils which such a fuel can contain. He proposes to call such a fuel "safety gasoline" (name suggested by R. Ferrier). (Paul Dumanois in *Comptes Rendus des Séances de l'Académie des Sciences*, vol. 183, no. 25, Dec. 20, 1926, pp. 1261–1263, *teA*)

INTERNAL-COMBUSTION ENGINEERING (See also Aeronautics: A Non-Backfiring Carburetor for Aircraft Engines; Fuels and Firing; also Power-Plant Engineering: Trends in Power-Plant and Electrical Development During 1926—Superchargers)

A Billet-Piercing and Tube-Rolling Mill

A modification of the Mannesmann mill, Fig. 3, consisting of two pairs of rolls, *a, c, b, d,* of which one initiates the hollowing process, while the second pair produces the rolling of the tube over the mandrel. Each of the rolls of one pair (*a, c*) and each of the rolls of the other pair (*b, d*) are located close to each other as regards their free ends and the roll pairs together constitute a pass that at first contracts and then expands. The first pair of rolls (*a, c*) consists of cylindrical and the second pair of conical rolls, the arrangement being such that the forward end of each of the conical rolls projects into the hollowed-out end of the cylindrical roll next to it. (Austrian patent No. 104,010, issued to the Sack Machine Mfg. Co., Inc., and Engr. Jos. Gassen, abstracted through *Zeitschrift des Oesterreichischen Ingenieur und Architekten-Vereins*, vol. 78, no. 49/50, Dec. 10, 1926, p. 503, *d*)

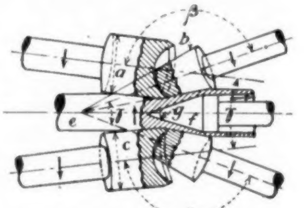


Fig. 3 Four-Roll Billet-Piercing and Tube-Rolling Mill

The Effect of Reduced Intake-Air Pressure and of Hydrogen on the Performance of a Solid-Injection Oil Engine

In an airship in flight, as the supply of oil fuel is consumed a corresponding amount of hydrogen must be released, and it thus becomes of importance to determine whether this waste hydrogen may be utilized to replace a portion of the oil fuel supplied to the engines.

The object of the experiments was to ascertain the effects of the admission of small quantities of hydrogen during the suction stroke, in the case of a heavy-oil engine of the solid-injection type.

Two sets of trials were run, one with coal gas and one with hydrogen. As it was thought possible that there might be trouble through detonation when hydrogen was being used, coal gas was first employed. Three series of trials were run, each being characterized by a different load, approximately 54, 39, and 25 b.hp., respectively. The speed of the engine was maintained sensibly constant throughout, and care was taken to insure that the jacket-water outlet temperatures were also sensibly the same in all tests.

In each series tests were run with varying amounts of coal gas, the maximum amount of gas being in the neighborhood of 5 per cent by volume of the air supply. At the lightest load employed this amount of gas corresponds to approximately 2.4 times the weight of fuel oil supplied.

After the trials with coal gas had been concluded, a corresponding set of three series of trials was run using hydrogen. The maximum amount of hydrogen admitted was slightly over 3 per cent by volume of the air supply. At the lightest load used, the corresponding weight of hydrogen is about 14 per cent of the weight of fuel oil used.

In each trial two 90-deg.-advanced diagrams were taken with the optical indicator, while observations of brake horsepower and consumption of air, gas, and fuel oil were recorded.

General. No ill effects of any kind ensued from the use of gas, nor were any indications of preignition or detonation experienced, and it was found that when any appreciable quantity of either coal gas or hydrogen was being admitted, the engine appeared to run more sweetly.

At any particular load, as more gas is introduced, the supply of fuel oil is automatically diminished, and it appeared that there might be some variation in the timing of the lifting of the sprayer needle valve due to this cause. It seemed important to settle this point, since any variation in the timing of the injection would in all probability produce effects which would mask the true effect of the gas admitted.

To clear up this point, the "spark indicator" previously mentioned was devised, and observations were taken of the needle-valve action when injecting widely different quantities of fuel. The results indicate that the quantity of fuel injected has no effect on the point in the stroke at which the needle lifts.

Effect of Hydrogen. At all loads, the admission of hydrogen causes a slight reduction in the brake thermal efficiency. The rate of decrease in efficiency as the ratio of weight of hydrogen to weight of fuel oil is increased, is roughly independent of the load on the engine.

Effect of Coal Gas. In the case of coal gas, at any given load the fall in efficiency appears to be directly proportional to the ratio of weight of coal gas to weight of fuel oil, while the rate of decrease in

efficiency becomes more rapid as the load on the engine is reduced. It will be observed that while at the highest load dealt with the admission of a given volume of hydrogen produces a greater fall in efficiency than the admission of the same volume of coal gas, at the lowest load approximately the same effect is produced by either hydrogen or coal gas.

Heat Loss to Exhaust. The admission of small quantities of either coal gas or hydrogen gives rise to a slight increase in the temperature of the exhaust gases. The rate of increase of exhaust-gas temperature with increase in the amount of gas admitted is approximately the same at all loads, and is unaffected whether coal gas or hydrogen is in use. Thus each 1 per cent increase in the ratio by volume of gas to air causes a rise of approximately 10 deg. fahr. in the temperature of the exhaust gas.

Combustion and Expansion. It appears that the admission of such small quantities of hydrogen or coal gas as were employed in the present investigation leads to a slowing down of the rate of combustion accompanied by a reduced maximum pressure. With amounts of hydrogen up to 3 per cent and coal gas up to 5 per cent by volume of the air consumption of the engine, there is no noticeable preburning during the compression stroke, and the point in the stroke at which combustion starts is controlled by the oil-fuel injection. The rapidity of the pressure rise following the initiation of combustion appears, however, to be reduced by the admission of gas, coal gas producing a greater effect in this direction, volume for volume, than hydrogen. There are also indications that, as the proportion of hydrogen to air is increased beyond a certain point, the slowing-down effect on combustion ceases.

Over the range covered by the present experiments, it appears that the rate of decrease in maximum pressure with increase in the amount of hydrogen admitted is the same for all loads, and that each 1 per cent increase in the ratio of hydrogen to air by volume causes the maximum pressure to be reduced in amount by 4.3 lb. per sq. in.

In the case of coal gas the rate of decrease in maximum pressure appears to be greater at reduced loads. At the highest load dealt with (54 b.hp.), each increase of 1 per cent in the gas-to-air ratio causes a reduction of 4 lb. per sq. in. in the maximum pressure, while at a load of 24.5 b.hp. the corresponding reduction is 8 lb. per sq. in.

REDUCED INTAKE-AIR PRESSURE

Range of Investigation. The object of the experiments was to determine the effects produced on the performance of the engine by throttling the air intake, with a view to predicting the performance of the engine under altitude conditions.

Four series of trials were run, each at a different load, namely, 24.1, 38.7, 53.2, and 68.1 b.hp., the speed being constant. At each load trials were run with varying degrees of throttling of the air intake, the degree of throttling being measured by the pressure at the end of the suction stroke as found from the light-spring diagrams. The range of suction pressures investigated included down to approximately 2 lb. per sq. in. below normal for the highest load (68.1 b.hp.), and down to approximately 6 lb. per sq. in. below normal for the lightest load (24.1 b.hp.)

Conclusions. When running at constant speed and developing a constant brake horsepower, a reduction of suction pressure appears to lengthen the time interval between injection of the fuel and the start of combustion. The rate of pressure rise after combustion has started appears to be unaltered by a reduction of suction pressure, while at any given load the magnitude of this pressure rise remains approximately the same at all suction pressures. The maximum pressure is decreased as the suction is reduced, while more heat is evolved by combustion during expansion. The temperature of the exhaust gases is increased, as also are the heat losses to the jackets. These effects become more pronounced as the load on the engine is increased.

In consequence of the above effects, the brake thermal efficiency is decreased by a reduction of suction pressure, while the fuel consumption is increased, these effects becoming relatively greater with increase in the load on the engine. Thus, at 68.1 b.hp. a reduction of 2 lb. per sq. in. in the suction pressure results in the brake thermal efficiency being reduced by some 17 per cent of the efficiency under normal conditions, while at 24.1 b.hp. the corresponding reduction in efficiency is 4.4 per cent of the normal value appropriate to this load.

Application to Altitude Conditions. Subject to certain corrections, a reduction in suction pressure by throttling the air intake causes the same effects on the engine as are produced by altitude conditions. A table is given in an appendix to the original paper whereby the results of the throttling trials may be applied to altitude conditions.

In general, the brake thermal efficiency falls as the altitude is increased, the rate of fall being greater at high than at low loads. At light and moderate loads the first few thousand feet above ground level cause but a slight change in the brake thermal efficiency, but as soon as the air-to-fuel ratio is reduced to a value of approximately 30, the fall in efficiency with further increase of altitude is very much more rapid. (G. F. Mucklow in the *Journal of the Royal Aeronautical Society*, vol. 31, No. 193, January, 1927, pp. 17 to 48 and discussion, 48 to 59, 13 figs. in original article and 3 figs. in discussion, *ep*)

The Torque Converter

DESCRIPTION of the Constantinesco device, which in a general way is already known in this country and which has lately been applied to an automobile, but which is applicable in many other ways—for example, in the driving of machine tools, etc.

In introducing Mr. Constantinesco prior to the presentation of his paper before the Royal Society of Arts in London, December 1, last, the chairman, J. Swinburne, F.R.S., explained the action of the converter in popular language, and it is his explanation that is reproduced in part in the present abstract.

Consideration of two cones and a belt, the boll and disk, and of the double-cone belt grip of the motorcycle, Mr. Swinburne said, showed they were all imperfect mechanically. Various methods of making pulleys alter their diameters had been tried. Generally they had resulted in polygonal wheels.

There had been schemes for working a ratchet wheel by a pawl whose stroke was varied by some form of link motion. As the driven wheel should move uniformly, and the pawl generally moved harmonically, incompatible motion gave trouble and broke teeth, or driving gear.

The hydraulic method with two pumps whose stroke could be varied was a good paper solution; but leakage and elastic compression of the fluid gave trouble, and the mechanism was apt to be heavy and expensive. Many engineers treated water as incompressible. In the presence of the author, who had utilized the volume elasticity of water commercially for transmitting power, they must be careful.

The main or driving shaft of the engine worked a connecting rod with a uniform stroke, say, of 6 in., as an example. If the end of the connecting rod were pivoted to the middle point of a lever roughly at right angles to it, it would move the lever bodily to and fro 6 in. Fig. 9 showed a lever, except that, for simplicity, the connecting rod was pivoted to the middle and not near one end. Let the arms of the lever be equal. Each end moved 6 in. If one were held still, the other moved 12 in. to and fro; the sum of the movements of the ends of the lever was always 12 in. The Constantinesco principle was to provide two paths for the energy involved in a movement of the main connecting rod. In this case it might move either end of the lever or both ends. At one end was an energy store in the form of a mass of metal whose inertia modified the movement of its end of the lever. This might be called the storage end of the lever. At the other end the lever might work a pair of rods with pawls gearing into ratchet wheels on the driven shaft; so that any movement of this end of the lever rotated the driven shaft in one direction. This might be called the business end of the lever.

If the business end were held immovable the main connecting rod would vibrate the mass or weight through 12 in. If the speed were high, this meant that the mass had great kinetic energy twice a revolution of the driving shaft, at the instants of maximum speed. But this energy was not wasted. It was taken from the connecting rod at one part of each half-stroke, and returned during the other.

If the storage end were held immovable, the business end vibrated through 12 in., and the driven shaft was ratcheted round at the maximum speed.

If they now took the case of no load on the driven shaft, the business end would then vibrate 12 in., and the speed would be the maximum. The engine would tend to run away. Imagine the load slowly increased; there was an opposing force at the business end, and an equal force on the mass; the mass would therefore move a little, so that at any instant the sum of the velocities of the ends of the lever, taken in the same direction, was equal to twice the velocity of the middle of the lever; and the force on the ratchet was equal to the acceleration of the mass, or to its deceleration. As the load increased, and as the mass took its share of the movement, the stroke of the business end became less, so that the speed of the driven shaft became less, while the torque increased. This change went on as the torque increased, and until the torque of the driven shaft stopped its turning. It took in energy and returned it again to the engine. There was no external work, so the engine had no load and tended to run away. But the force needed to wag the mass increased as the square of the speed, so the force on the ratchet and the torque on the driven shaft increased quickly—and sooner or later the shaft was turned.

Within the limits of speed this gear thus looked after itself if one merely controlled the engine. Whatever power the engine gave, the gear transmitted it to the driven shaft at the speed at which the shaft must run to absorb that power.

The pawl and ratchet were merely taken for ease of explanation; they were not used.

To follow the action a little more closely during a stroke: when working, the driven shaft ran at uniform speed, so while the pawl was against the tooth the business end of the lever was moving at uniform speed, though the middle point of the lever was moving harmonically. The mass was moving so that its acceleration was proportional to the force on the ratchet. The ratchet and pawl thus moved uniformly, and the mass moved according to the force on the ratchet, and the gear thus adjusted itself so that there were no high forces due to incompatibility of motions. Neither end of the lever thus moved harmonically. The business end moved uniformly during the working part of the stroke, and the storage end moved, so that the sum of the two motions was harmonic. At the instant when the pawl came up to the speed of the ratchet, it was moving at the same speed as the ratchet. As the lever tended to increase this speed it was resisted by a force gradually increasing from zero, which meant acceleration force applied to the mass, also increasing from zero and also always finite.

This point was important. As the variable-stroke ratchet gear operated direct from the main shaft would not work, because the pawl was moved harmonically while the ratchet moved uniformly, it might be thought that the Constantinesco gear involved at least some of the trouble.

This was not the case, however, because the push from the main shaft had the choice of two paths, into the driven shaft, or into temporary storage of energy. The action of the gear was thus quite gentle and smooth in comparison with the power transmitted.

If the action of the storage mass were considered, it was found that it always took up energy from the main shaft; but when any power was being transmitted it gave part of this back and gave the rest to the driven shaft; this portion being bigger as the external power increased.

The fundamental principle was thus, that the driving shaft reciprocated an element so that its motion had a choice of two freedoms. It might move one part so as to do external work, or it might move the other so as merely to store energy for a quarter of a period or so; or it might do both. The floating lever was taken as a simple example. There were many other ways of giving the choice.

As to the ratchets and pawls, these were replaced by clutches or "valves" made on the principle of very highly developed bicycle free-wheel gears. They were made so that the squeeze was taken by a number of rollers instead of one, and there was practically no loose motion or backlash. Though one element of each valve was reciprocating rapidly, no part of the mechanism had excessive stresses on it. Compared with gear wheels which transmitted large power by very few teeth at a time, the valve ought to last well.

As the contact of a roller with its race, under no load, was a line, the roller had to flatten out a little under a load. Roller bearings, and still more, ball bearings, were thus resilient. Though balls and rollers were admirable for nearly all bearings, this pointed to danger if they were used for any axles which should run true on their axes in spite of rapidly varying side stress. It was doubtful, therefore, if balls or rollers should be used for milling-machine or lathe mandrels, except to take end thrust.

The resilience of the roller bearings allowed the valves to be used for many purposes without any mass or storage element. A valve worked at constant stroke in, say, a drilling machine, would go fast at light loads and slow at heavy.

As to the applications of the Constantinesco gear, the most important was the railway locomotive. A steam engine could develop its maximum power at high speed only. At starting it could not develop a high torque, and the power was very small. If one could use even 500 hp. in starting a train it would accelerate very quickly. The loss of time in an ordinary journey over a long up-grade could not be made up by racing over the flat part of the journey. What was economical and fast was uniform power. But the gear also enabled the locomotive to use an oil engine, especially in countries where there were difficulties about coal; and might simplify and improve electric traction also.

The action of the gear when the primary shaft was driven either at constant speed or at constant torque and varying speed was difficult to think out. In a motor car, the driver merely controlled the engine by the throttle, and whatever power the engine gave was handed over to the wheels, the gear settling so that the car took that power, not more and not less. There was thus no gear box, or gear changing. Reversal was by changing the valve action. The interposition of a gear depending on storage of energy in a mass between the driving and driven shaft, presented problems of which the solutions often seemed indeterminate. Thus if an engine gave absolutely constant torque at varying speed, or absolutely constant speed independent of torque, the results were indeterminate. In practice engines did not work so, and the system was controlled completely by controlling the working fluid of the engine. (*Journal of the Royal Society of Arts*, vol. 75, no. 3866, Dec. 24, 1926, pp. 145–148, *d*)

The Etchegoin-Causan Engine

From the description given, it would appear that this engine deserves the utmost attention because of the very large output for its size. Among other things, it is stated that on July 13, 1926, a boat equipped with such a motor won at an international contest the Auto-Nautique cup of France, and on a bench test developed for 6 hr. an output of 120 hp., notwithstanding the fact that it has only 1500 cu. cm. (91.5 cu. in.) of cylinder volume.

The motor, Fig. 4, works on a two-stroke cycle and is fed through a Roots-type rotary blower, equipped with a bypass to permit the regulation of scavenging in such a manner as to obtain either the most economic operation at normal or low output, or a high output with complete scavenging. The scavenging and feeding of the cylinder are effected through admission and exhaust ports located respectively at each extremity of the cylinder and uncovered by the motor pistons themselves, the regulation of distribution being obtained either by the proper staggering of the two crankshafts or by the location of the ports themselves. With this method of feeding and a two-stroke cycle it became possible to run the motor at 4400 r.p.m. and yet obtain absolutely correct scavenging and filling.

The compression chamber, which is also of course the combustion chamber, is in the shape of a cylinder of a diameter equal to the bore and a height equal to the distance between the two pistons when they are close together, i.e., when both of them are at their upper dead point. At this point ignition takes place from a magneto with the necessary advance, the spark plug being located in the middle of the cylinder and hence directly inside the combustion chamber. The thermal efficiency is a maximum on account of the shape of the combustion chamber. Moreover, the cylindrical part of this explosion chamber may be equipped with several spark plugs and hence several equidistant ignition points. The power developed by the explosion is applied to the faces of the two pistons, which are therefore at the same time

motor piston and valve piston. From the point of view of the inertia of elements in motion, the engine may be considered as having twice the number of cylinders it has, but only the actual number of cylinders from the point of view of losses through the walls. It therefore has the advantage of an engine with a large number of cylinders without some of their disadvantages. Moreover, with its simplicity of construction it is more reliable than the conventional motor having a number of delicate devices, such as valves, springs, camshafts, etc., all of them subject to failure as a result of vibration, temperature changes, etc. It is believed that in an aviation motor, air cooling would be possible. [The foregoing information has been obtained from the first instalments of the article, and an effort will be made to report further information of interest if and when it becomes available.—Editor.] (A. Berreur in *L'Aérophile*, vol. 34, no. 23–24, December 1 and 15, 1926, pp. 361–363, 5 figs., *dA*)

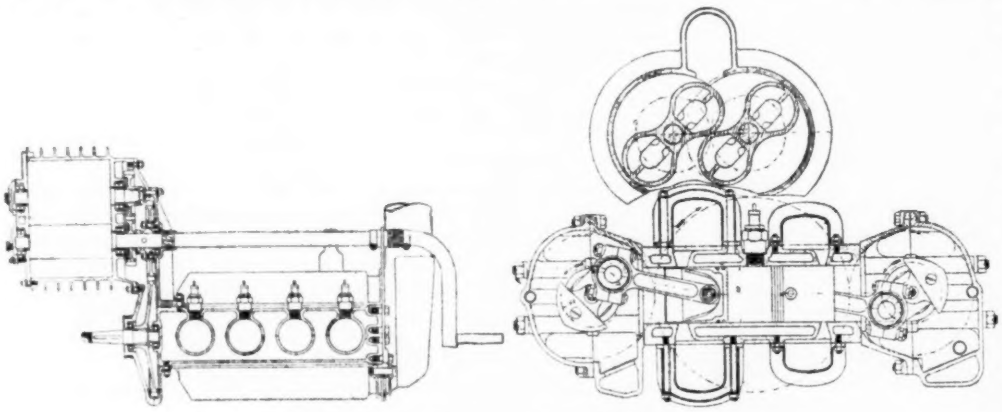


Fig. 4 The Etchegoin-Causan Engine
(Left: Vertical section with the blower at the upper left-hand corner. Right: Section through one of the cylinders showing the blower on top.)

MACHINE PARTS (See also Power-Plant Engineering: The Luc-Denis Expansion Joint)

The Selflock Lock Nut

A lock nut has been designed which can be used in conjunction with bolts having U.S. standard threads, can be repeatedly put on and taken off, and does not have any movable parts. It is made by the Graham Bolt and Nut Company, Pittsburgh, Pa.

In this lock nut the pitch-line location is the same as on a bolt having a U.S. standard thread; the thread form inside the pitch line is identically the same as the U.S.S., while outside the pitch line the thread angles are slightly changed. There is, however, no distortion of the thread, the lead being true U.S.S. and the helix angle constant. Due to the equal thread areas, no material is removed when Selflock nuts are applied on U. S. S. threaded bolts. The lead being true U.S.S., the nut may be applied from either face, the holding power developed being the same in either case.

When Selflock nuts are applied, that part of the thread on the bolt lying outside the pitch line is slightly tipped so as to create a definite frictional lock on every thread engaged by the nut. Should it be necessary to remove the nut it will require more wrench load to break the contact and start the nut off the bolt than was required to put it on. The Selflock nut is applied in the usual manner—started with the fingers and wrenched to position.

U.S.S. nuts may be applied to bolts having had Selflock nuts on them. Should the U.S.S. nut be reasonable in size, a certain frictional load will be developed as it will be necessary to bring the thread on the bolt back to suit the U.S.S. conditions in the nut. Selflock nuts may be applied many times to the same bolt thread. Should this be done so many times that sufficient lock is not developed, the nut can be reversed, when the locking feature will again function.

Because of the fact that the locking feature of the Selflock nut is cut into the solid metal of the nut, it is impossible for the workman to change its locking value in any way—the nut cannot be normalized. (*Railway Age*, vol. 82, no. 2, Jan. 8, 1927, pp. 191–192, *d*)

MANAGEMENT

Individual Differences in Accident Rates

An investigation of the accident problem in which an attempt is made to answer the following two questions: (1) Do individuals, in fact, differ in their individual susceptibility so that under equal conditions of risk some will incur accidents while others will escape? and (2) and if this is so, in what measurable respect do such susceptible individuals differ from their fellows? It is with the second question that the present investigation deals particularly. A number of tests are described and their results given. These tests are summarized in the form of a table. Some of the apparatus used in this is described in the appendix, in particular, a self-recording dotting machine and a pursuit meter.

From the experiments carried out, the report states, the definite conclusions can be drawn that inequality in accident liability is not solely determined by external factors or by chance, but is due in an appreciable degree to measurable individual differences. Even complete knowledge and perfect measurement of such personal differences will never make it possible to say with certainty whether any particular individual will or will not sustain an accident under given circumstances, but the present results suggest that it is practicable to determine in a rough way the probability of any individual sustaining an undue number of accidents, and as more research work is done and the methods become refined, this probability should tend to approximate more and more to certainty. It must, however, be borne in mind that at present the reliability of the tests has not been established, and until this is done they cannot safely be used for prognosticating the accident proneness of individuals.

A relationship has been shown to exist in the subjects examined between accidents on the one hand, and poor "aestheto-kinetic coördination" and nervous instability on the other. No relation has been found between accidents and the higher intellectual processes. The intermediate processes involving the special abilities and more highly integrated aestheto-kinetic coördination have not been examined.

There is a slight indication that the accident-prone are industrially inefficient and more liable to report sick, and so react unfavorably on their total environment. This needs confirmation.

No attempt has been made to distinguish between specific and general factors in personal proneness to accidents. This will have to be examined in a further inquiry.

A positive correlation has been found to exist between major and minor accidents in most of the groups examined. The relationship differs in different trades and in some does not seem to exist.

The final weighted results show a difference of 48 per cent in accident rate between those above and those below the averages in the tests. (*British Medical Research Council*, Industrial Fatigue Board, Report No. 38, by Eric Farmer and E. G. Chambers, 1926, 44 pp., 6 figs., *ep*)

MEASURING APPARATUS

The Klydonograph Surge Recorder

This is a new instrument for obtaining a continuous graphic record recording magnitude, time of occurrence, steepness of wave front, polarity, and character of electric surges (by character is meant whether or not the surge is oscillatory). It is a photographic device and utilizes what are known as Lichtenberg figures reproduced on a photographic plate. The construction of the device, its principles of operation, and connections are shown in the original article. It is particularly valuable for testing lightning arresters, but may be applied to the investigation of other elec-

trical phenomena. (J. H. Cox, Engineering Department, Westinghouse Electric and Manufacturing Co., in *The Electric Journal*, vol. 24, no. 1, Jan., 1927, pp. 5–9, 17 figs., *d*. Compare also in the same journal the article, Switching-Surge Investigations with the Klydonograph, by P. A. McAuley, pp. 9–13, 3 figs.)

POWER-PLANT ENGINEERING

The Luc-Denis Expansion Joint

THIS expansion joint is extensively used in France and is manufactured in England. With this joint the expansion of adjacent pipes is provided for by a rotary movement of a pair of flanges, which are coupled together, with pipes joining the limbs of a lazy-tongs arrangement. The pipe layout required to provide for this rotary motion is quite simple; it is only a matter of arranging the expansion joints in both vertical and horizontal planes to get unrestricted movement.

Fig. 5 shows an expansion point for a pipe of 14 in. bore. It will be seen that it consists of two bends, to one flange of each of which is rigidly bolted a thick facing ring, the joint between the ring and the flange being a metal-to-metal one. The bolts only indirectly play a part in holding the two flanges and their facing rings together. This coupling is directly effected by an outer ring, which covers the joint between the two facing rings, and is screwed to one of them, while the connection is made with the other by means of a ring of steel balls in the position shown in the figure. It will thus be clear that the pressure tending to force the bends apart is opposed by the shearing strength of the ring of balls on the edge of one facing ring, and the resistance of the stripping of the thread on the edge of the other. The employment of the balls permits the bends to rotate relatively to one another. As this rotation might tend to screw the outer ring, risk of this is overcome by fitting its lower face with a number of set screws. When the outer ring is correctly placed to give the proper alignment of the halves of the ball race, these set screws are adjusted against an extension of the flange of the lower of the two bends. The ring is thus locked in position. (*Engineering*, vol. 123, no. 3183, Jan. 14, 1927, p. 37, 2 figs., *d*)

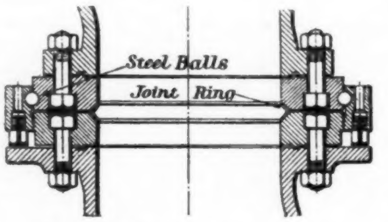


FIG. 5 THE LUC-DENIS EXPANSION JOINT

12,495 B.t.u. per Kw-Hr.

THE Columbia Power Station of the Columbia Power Co., located on the Ohio River twenty miles below Cincinnati has completed the first year of service. The operation during the month of October, 1926, showed an economy of 12,657 B.t.u. per kw-hr. In November, 12,529, and in December, 12,495 B.t.u. per kw-hr., all net sendout.

The turbine equipment consists of two General Electric tandem units of 45,000 kw. each, the high-pressure unit of fourteen stages being mounted on a single shaft with the low-pressure unit of twelve stages. The steam pressure at the throttle was initially 550 lb. at a total temperature of 725 deg., but was raised to 600 lb. at a total temperature of 730 deg. The steam at a pressure of 110 lb. is reheated between the high- and low-pressure cylinders to a temperature of 725 deg.

The furnaces are of the air-cooled refractory type and use pulverized coal as a fuel. The kilowatt-hour sendout to which reference was made above is the net kilowatt-hours supplied to the transmission lines exclusive of all power and light used in the station, for coal unloading, storage, and coal preparation. The original article gives very complete information as to the operation of the plant. (C. W. DeForest, Vice-President Columbia Power Co., in *Power Plant Engineering*, vol. 31, no. 3, Feb. 1, 1927, pp. 181–185 5 figs., *d*)

Chimney Reconstruction

IN THE CASE described in the present article it was found that the area of the opening of the chimney was about 50 per cent too small to meet requirements. There was no site available for building an additional chimney, and the question was how to erect a new chimney without interfering with the working of the boilers. The existing chimney was built of reinforced concrete and the foundations were found to be sufficient to carry the new chimney, the only difficulty being to get the proper connection between the foundation and the new shell.

To overcome this difficulty a new foundation was concreted on top of the existing one. In order to get proper connection, a tunnel was made under the existing flue and a heavy ring of reinforcement placed in position. This new foundation is not able to take the full load from the new chimney, and part of this load must be carried directly to the old foundation. The existing chimney had, however, a taper of 1.25 per cent, and thus the diameter at the bottom was ample for the new requirements. It was therefore decided to concrete against the existing chimney on the lower 16 ft. and not demolish this part of the old chimney. In other words, the new chimney is partly fixed to the existing one on the lower 16 ft. and through this part the stresses are carried directly to the old foundation.

As the work is progressing at the rate of one belt a day, quick-hardening portland cement is being employed and has given excellent results with regard to both strength and appearance of the finished work. The gaging used is one part cement to $1^1/_2$ parts sand to $2^1/_2$ parts shingle. (*Concrete and Constructional Engineering*, vol. 22, no. 1, Jan., 1927, pp. 29–30, 1 fig., *d*)

The Sulzer 1500-Lb. Boiler

DESCRIPTION of a boiler plant operated in the Sulzer Works at Winterthur, Switzerland, and employing a working pressure of 110 atmos. (1565 lb.) gage per sq. in. with a total steam temperature of 707 deg. fahr. Steam under these conditions has a total heat of 1232.8 B.t.u. per lb., and its available heat when expanding down to a 29-in. vacuum is 452 B.t.u. per lb., giving a Rankine efficiency of 38.1 per cent.

The boiler consists of two separate steam-raising units, one of which works at the full pressure and temperature, and the other at 14 atmos. or practically 200 lb. per sq. in. with a steam temperature of 662 deg. fahr. The low-pressure part serves as a feedwater heater for the high-pressure part. The principal object of the arrangement chosen was to study the practicability of improving an existing low-pressure boiler plant by the addition of boilers working at much higher pressures.

Firing is by pulverized coal on the unit system. Below the coal burner is placed an oil burner which facilitates ignition of the coal when starting from cold. Across the bottom of the combustion chamber is a water screen composed of eleven 3-in. seamless tubes expanded into square headers and connected to the low-pressure part of the boiler. The object of this screen is to chill the falling particles of molten ash and slag, so that they fall as dust instead of caking on the floor of the furnace and forming a deposit of clinker difficult to remove when the boiler is in service.

The front and side walls of the furnace are cooled with air which circulates several times up and down in closed ducts before passing eventually to the air heater. A pipe connects the latter directly with the burner. The air heater is arranged at the back of the low-pressure boiler, and an induced-draft fan situated on top of the boiler creates the necessary draft. Both the high-pressure and the low-pressure parts of the boiler are fitted with separate superheaters. The high-pressure superheater is designed as a radiant-heat superheater, and is built into the front wall opposite the high-pressure boiler tubes. The low-pressure superheater is of the usual construction and lies between the two parts of the boiler; it can be bypassed if desired.

The two drums for the high-pressure boiler are forged from solid ingots. The material is 5 per cent nickel steel.

There are twenty-four seamless high-pressure water tubes, with an external diameter of 60 mm. (2.36 in.) and a wall thickness of 7 mm. (0.276 in.). The average length of these tubes is 12.8 m. (42 ft.). Both ends of each water tube are beaded into the high-pressure drum. The tubes are seamless hot-rolled Mannesmann tubes, tested to 200 atmos. (2845 per sq. in.) and are of specially selected quality, having a tensile strength of 24 to 29 tons per sq. in., with a minimum elongation of about 20 per cent. The tubes

of the high-pressure superheater are of the same material. They are 32 mm. (1.26 in.) external diameter and 3.5 mm. (0.138 in.) thick.

Fig. 6 shows diagrammatically the arrangement of the plant. The raw water is obtained from the Winterthur town mains, and has a total hardness of about 22 French degrees. After preliminary treatment in a Sulzer purifier, it enters the raw-water tank shown in the left-hand bottom corner of the diagram. From this tank it is fed into the low-pressure boiler by means of a low-pressure centrifugal pump working against a pressure of 14 atmos. The make-up feed for the high-pressure boiler, which amounts to about 5 per cent of the high-pressure steam produced, is provided as follows: The required amount of saturated steam from the low-pressure boiler passes down into a preheater having the form of a surface condenser. The steam is condensed in this apparatus, and passes from it into the distilled-water tank. The water from this tank, which has a capacity of about 20 cu. m., or 4400 gal., is the water which serves to condense the steam in the preheaters. The bulk of the water in this tank is the condensate from the high-pressure steam after use. This water is forced by a centrifugal pump working at a pressure of 230 lb. per sq. in. through the degasser and through the preheater to the suction side of the high-pressure feed pumps. In passing through the preheater it is raised to a temperature of about 190 deg. cent. and is fed into the high-pressure boiler at that temperature by the high-pressure feed pumps. There are two of these pumps, each capable of supplying the boiler at full load with adequate feedwater at a pressure of 120 atmos., or 1700 lb. per sq. in. One of the pumps is steam driven and the other is electrically driven, an oil gear being fitted between the pump and motor in the latter case in order to avoid the necessity for a variable-speed motor. When used for heating purposes the steam from the high-pressure boiler is passed through a reducing valve into the steam distributor and thence to the heating system. The condensate from the system flows back to the distilled-water tank, thus completing the circuit. The surplus steam raised in the low-pressure boiler can also be used in the heating system, both the high-pressure and the low-pressure steam being led away together after passing the reducing valve. When the low-pressure steam is used in this way, the low-pressure boiler can, of course, be fed with distilled water, except for the amount of make-up required.

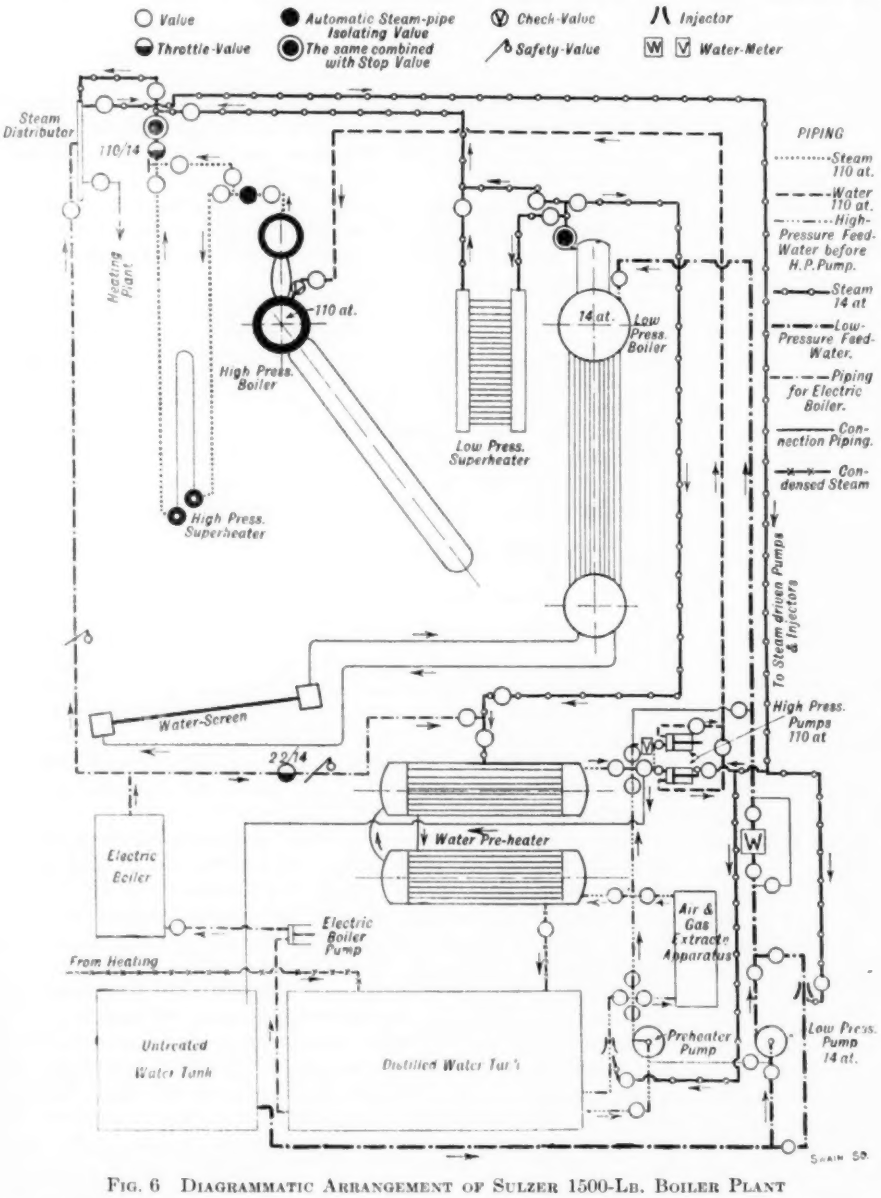


FIG. 6 DIAGRAMMATIC ARRANGEMENT OF SULZER 1500-LB. BOILER PLANT

As stated above, the main purpose of this plant was to explore the possibilities of improving existing low-pressure plants, but there were other considerations which indicated the advisability of such a procedure. The low-pressure section, which is obviously much less costly than the high-pressure portion, is quite adequate to extract the heat from the partially spent flue gases. Thus the two pressure system avoids the installation of expensive high-pressure heating surface in the region of low gas temperatures, where the rate of heat transmission is low and the surfaces therefore have to be correspondingly large. The low-pressure boiler can provide these large surfaces without undue cost, leaving for the high-pressure boiler the duty of intensive heat absorption where the temperatures are greatest. The low-pressure boiler, moreover, provides, as has been seen, a distilled feedwater at a very high temperature for the high-pressure boiler, and thus at the same time preserves the latter boiler, protects it from scale, and relieves it, as far as possible from the work of warming water. (*The Engineer*, vol. 142, no. 3703, Dec. 31, 1926, pp. 706–709, 5 figs., *dA*)

Trends in Power-Plant and Electrical Development During 1926

IN THE section of the January *General Electric Review* dealing with progress in radio receiving during 1926, from which journal this abstract is taken, the following statement is prominently displayed: "The invention of any device that makes possible some new and remarkable accomplishment can for a time rest upon its laurels, but not for long. Increase in familiarity with its operation soon replaces the initial fascination with which it was regarded, and leads to substantial progress along engineering lines."

There was, the article under consideration states, a remarkable increase during 1926 in the unit capacity of turbine-generator sets, particularly those under construction. Thus a 208,000-kw. unit has been ordered for installation in 1929, and the fact that this and several other large units are being constructed for dates of installation so far in the future, is an impressive illustration of the foresight necessary today in the central-station industry.

During the year two important stations were placed in service, The Columbia Park Station of the Columbia Gas & Electric Co., and the Richmond Station of the Philadelphia Electric Co. In the former, 245,000-kw. tandem-compound units with single flow in the low-pressure end are installed, while the machines in the Richmond Station are tandem compounds of 60,000-kw. capacity, but with double flow in the low-pressure cylinder. At the time of design the generator in each of these cases was regarded as

the conservative maximum limit of capacity in units running at 1800 r.p.m. The new units ordered for the State Line Station and running at the same speed have an output more than three times as large as that of the Richmond Station machines.

A 52,000-kw. single-cylinder 1500-r.p.m. unit built for the Southern California Edison Co. is now in service, and two 94,000-kw. 1500-r.p.m. tandem-compound units, each consisting of a 90,000-kw. 100,000-kva. 16,500-volt main generator and a 4000-kw. auxiliary generator, are in process of construction.

The main generators of these latter units exceed in both capacity and physical dimensions any electric generator previously built, and the turbines are also the largest of the tandem-compound type so far constructed. Each turbine-generator will measure 103 ft. in length and weigh about 1,650,000 lb.

Other unusual features of these machines include provision for future gas cooling of the generators and the combination of a double-flow, low-pressure end with four vertical condensers. They will be the first of their type to generate current at 16,500 volts.

The Emmet Mercury-Vapor Process. Some changes were made in the past year in the Hartford installation previously described in Mechanical Engineering. Among others, the former single-stage mercury turbine was replaced by a three-stage unit having an efficiency of 70 per cent, and it is believed that a five-stage machine would be about 75 per cent efficient.

It is expected that a large commercial mercury unit will be constructed for installation at the South Meadow Station of the Hartford Electric Light Company. It is estimated that it will consume 14,400 lb. of coal per hour and will deliver 10,000 kw. from the mercury generating unit. In addition, the condensing mercury will generate 124,000 lb. of steam per hour which will be superheated to 750 deg. fahr.

Turbines with Process-Steam Delivery. Several installations of this kind have been made. Thus at the Raritan Copper Works at Perth Amboy, N. J., where there is in connection with electrolytic refining of copper a demand for large amounts of both power and process steam, two 5000-kva. and one 3125-kva. automatic extraction turbine-generators were installed.

These three units operate at 3600 r.p.m. and were designed to receive steam at 365 lb. gage pressure and 200 deg. fahr. superheat at their throttles. The prime movers previously installed utilized steam at 165 lb. gage pressure.

The two 5000-kva. machines were designed to exhaust against $1^1/_2$ in. of mercury absolute back pressure. Each was equipped with an internal grid valve and auxiliary throttle with auxiliary mechanisms to permit the extraction or reception of steam at 165 lb. gage pressure, in order that, when there is a deficiency of steam in the 165-lb-pressure system, steam may flow freely into it from the 365-lb-pressure system through the turbine to maintain the lower pressure constant. Each of the larger units will be equipped with an outlet for non-automatic extraction at approximately 30 lb., and with an internal grid-valve mechanism for the automatic extraction of steam at 2 lb. gage pressure. The latter was designed to maintain 2 lb. gage pressure in a low-pressure heating system throughout wide ranges of electrical output and steam extraction.

The 3125-kva. unit was designed to exhaust into a closed heating system, in which 6 lb. absolute pressure will be maintained, and is equipped with an internal grid valve to permit the automatic extraction of steam at 2 lb. gage pressure. The three units will be operated electrically in parallel. Through the shifting of electrical load from one to the other and through the automatic adjustments of the extraction mechanisms, it will be possible to obtain varying quantities of steam for process work without changing pressures in the several process-steam systems or appreciably impairing the high thermal efficiencies of the units.

Superchargers. The centrifugal type of supercharger, which was originally developed for use in connection with airplane engines for high-altitude flying, was embodied in a modified form intended for relatively low-altitude flight in a new type of air-cooled radial aviation engine.

The supercharger, or "rotary induction system" as it is now commonly known, is located between the carburetor and the intake manifold. In its latest form it is built directly into the engine crankcase, and does not materially affect either the size or the weight of the engine.

Its function is to draw gasoline and air through the carburetor and compress it sufficiently to overcome the normal pressure drop through the carburetor. This means that the mixture is delivered to the engine intake manifold at or slightly above atmospheric pressure. Engines of this class rated as high as 500 hp. have been so equipped.

Centrifugal Compressors. A line of compressors was constructed on entirely new pressure-volume considerations. The impellers are of the single-inlet radial-blade shrouded type, designed primarily to put energy into the air or gas. They are surrounded by highly efficient conversion passages where the kinetic energy received from the impeller is transformed into potential energy in the form of pressure.

Mechanical details were given very careful consideration in the designing, particular attention being focused on the rotor construction, lubricating system, packings, etc., with the result that the mechanical operation is excellent.

An outstanding example of the new design of compressor equipment for gas service was the installation at the Harrison Plant of the Public Service Gas & Electric Co. of N. J. It consists of four 25,000-cu. ft. 15-lb. gas boosters driven by extraction-type condensing turbines; eight 22,000-cu. ft. 20-lb. turbine-driven blowers, and four 14,500-cu. ft. 2-lb. turbine-driven water-gas exhausters. (John Liston, General Electric Co., in the *General Electric Review*, vol. 30, no. 1, Jan., 1927, pp. 4–66, 135 figs. Only a small portion of the article is abstracted, *g*)

RAILROAD ENGINEERING

Vacuum-Brake Tests on Long Freight Trains

Data of tests carried out on the Indian Government Railroads, with charts. Only the main conclusions can be reported here.

The first thing about the charts to strike the eye is the pronounced lag in propagation of pressure differences. There is not necessarily any real disadvantage in being unable to apply all the brakes of a long train simultaneously. The extent of any such disadvantage depends, first, upon the severity of the brake application, and secondly, upon the lag in propagation of the brake.

It is to the moderate pressure used in these trials that the remarkable smoothness of the stops can be attributed. The speed of propagation was rapid enough to prevent recoil; it was enough to permit of a progressive "piling up" of vehicles toward the front. But it must be recognized that this "balance" is easily liable to disturbance, and therefore "lag" will always be undesirable.

It would appear that the degree of vacuum maintained throughout these trials is about the best compromise. With the ejector relief valve set to lift at 20 in. when operating against a standard test orifice, 18 in. was maintained on the engine, while there was a pressure drop of about $2^1/_2$ in. at the rear of the train. Higher pressures would entail longer delays in creating vacuum or in releasing the brakes. Lower pressures would result in impaired train control, contributed to by decreasingly efficient braking toward the rear of the train on account of the rapid falling off in pressure differences, particularly in cases of long piston travel.

With the existing degree of visibility of signals, non-vacuum freight-train running speeds can hardly exceed 20 m.p.h. with safety. Speeds up to any economic limit can be run with perfect confidence with fully braked trains. An increase in running speed and increased confidence in the handling of freight trains by drivers might relieve, to some extent, pressure on congested lines. It is, however, too early to express an opinion as to—

1 Whether fully vacuumed freight tiains are a practical routine proposition, or

2 Whether, in this event, the advantages realized will be commensurate with the cost of the special arrangements involved.

Decided applications of the brake from the rear end of the train result in such heavy snatching in the front part of the train as to make train partings probable. The effect, as may be followed from a chart given in the original article, is after the style of that produced by dropping a weight tied on to a piece of elastic.

The rapid-acting valve in the rear brake car failed to open under any operating condition and such valves appear to be of no

value on long freight trains owing to the "lag" in propagation of the brake being too great to permit their coming into operation. This "lag" is about 50 sec. on full emergency applications. Had the valve come into operation, very little useful purpose would have been served; even the smoothness of the stops might have been adversely affected.

On the other hand, (*a*) it is very necessary to provide on such long trains some form of communication between guard and driver, and (*b*) to provide the guard with some means of stopping the train when necessary.

It is suggested that for (*a*) a whistle signal similar to that used by the Westinghouse Brake Company could be devised.

For (*b*) a small application valve should be provided. A large valve is undesirable, as a heavy application from the rear end would almost certainly lead to a train parting.

All the tests described in this report were conducted on level ground. (R. C. Case, Assoc-Mem. A.S.M.E., Locomotive Dept., E. B. Railway, in Technical Paper No. 254, issued by the *Railway Board, India*, but not as an official publication, July, 1926, 11 pp. of text and 14 charts, *eA*)

REFRIGERATION (See Air Engineering: Refrigerating as Applied to Air Conditioning); Testing and Measurements: Determination of Inside Temperature of Refrigerators

SPECIAL PROCESSES (See Air Engineering: Refrigerating as Applied to Air Conditioning; Welding: Cutting Metal Under Water)

TESTING AND MEASUREMENTS

Determination of Inside Temperature of Refrigerators

IN TESTING refrigerators it is often desirable to know how near the actual ice consumption and inside temperature come to the theoretical, and also to discover what should be the inside temperature and rate of melting in changes of outside temperature. In refrigerators of usual build considerable uniformity and agreement of a calculated result with an actual result may be expected when temperatures of given boxes are compared by differences (and these temperatures are taken at about the same relative location on the box), if the ice surface is kept approximately the same.

For example, if the same box or two boxes of exactly the same make-up are compared and the outside temperature of one box, its use of ice, also its outside temperature and its inside temperature at any one point (say, the center of the food chamber) are known, a fairly accurate calculation can be made of its use of ice at other outside temperatures, and the temperatures of the inside can be fairly accurately predicted. The calculation is very simple. Let—

O_1 = outside temperature of a refrigerator or temperature of room near the box
O_2 = outside temperature different from O_1
I_1 = inside temperature when outside is O_1
I_2 = inside temperature when outside is O_2
L_1 = pounds of ice when outside temperature is O_1
L_2 = pounds of ice when outside temperature is O_2.

and it is desired to find the use of ice under O_2 circumstances when O_1, L_1, and I_1 are known. The use of ice will be in proportion to the difference of the outside temperature and 32, or

$$L_2 = \frac{L_1}{O_1 - 32} \times O_2 - 32$$

The author shows that this formula gives satisfactory results. Among other things, he compares the results obtained from its use with certain data published by the Electrical Refrigeration Committee of the National Electric Light Association in June, 1925, and shows that the two are fairly consistent. He proceeds then to the consideration of the calculation of results that might be obtained in refrigerators by the use of better insulation, and compares for this purpose two boxes, one of which is assumed to be twice as well insulated as the other. He gives the numerical values derived from his formula and corroborates them with data from a test which he made with two boxes having the same surface.

The poorer-insulated box used 75 lb. of ice, the outside temperature being 82 deg. and the inside temperature, 53 deg.

The more highly insulated box used 62 lb. of ice at 82 deg. outside and showed an inside temperature of 48 deg. A calculation as above shows 48.42 deg. Great care was taken in the test to keep the ice surfaces at all times nearly the same, but of course it could not be done with mathematical exactness.

On different sizes of boxes at different ratios of transfer this method of figuring would hold good only if the ice surfaces and rate of circulation were proportional.

The numerical value of good insulation is indicated by the use of these methods of computation as showing the exact comparative figures that must govern in considering not only greater economy but lower temperatures obtainable by good insulation by heat reception of surfaces of fixed temperatures such as ice, and brings out the economy of using surfaces of the highest temperature available for taking up heat, for a machine will take up more heat with less power per unit of heat as the heat-receiving surface is higher. It also demonstrates that 32 deg. is amply low enough for the outside temperature difference from zero to take up heat for ordinary domestic purposes, considering the market prices for insulation. (John E. Starr, Mem. A.S.M.E., in *Ice and Refrigeration*, vol. 72, no. 1, Jan., 1927, pp. 86–87, *pe*)

VARIA (See also Power-Plant Engineering: Chimney Reconstruction)

The French "75" Gun

THE death of Colonel Deport, the inventor of the famous French "75," calls attention to the history of this weapon. This has been written up in detail by the collaborator of the inventor, Colonel Rimailho, in his *Artillerie de Campagne*, published in 1924. Deport, who was at the time manager of the shops at Puteaux, was ordered to undertake an investigation of this caliber of gun by General Mathieu, then chief of artillery. Special attention was to be paid to guns with automatic braking. Deport started his investigation on an 80-mm. cannon with a hydropneumatic brake. Tests made in October, 1892, made it possible to indicate the main essentials of the new device, which was to embrace the employment of a self-contained carriage, a breech with an eccentric screw, inclined planes to rest the cannon on the brake in passage, etc. It was only in November, 1893, that the first gun was completed and exhibited before the higher officials. On the whole it was very satisfactory, but showed a necessity of certain changes. When Deport left the service in November, 1894, the gun had been brought to the point of development where it could fire 25 shells per minute the shells weighing 7 kg. (15.4 lb.) and having a muzzle velocity of 500 meters (1640 ft.) per sec.

The hydropneumatic braking, however, was still limited in operation, and after a few shots it exhausted its reserve of liquid and air and became inoperative. The gun, therefore, could not be used under service conditions, and moreover the material of a complete battery was as yet entirely non-existent.

Then a very unusual thing took place. The development of the gun was entrusted to Captain Sainte-Claire-Deville, who some years before had begun to develop a rapid-fire gun of his own, which did not need any brake and shot small projectiles at the rate of 38 per min. and at a muzzle velocity of 570 meters (1870 ft.). This gun, it may be mentioned, was ultimately developed into a very useful weapon. The first idea was to redesign the Deport experimental gun along the lines of the latter gun, combining the best features of the two, but on thorough investigation Captain Deville decided that the Deport gun was entitled to an independent development of its own and for the time abandoned his own device, a plan of behavior which is not often adopted by inventors in high official positions. The Deport brake was rejected, however, and a new device developed by Deville, and the first unit built according to his new plans withstood successfully the test of firing 10,000 shots.

In 1896 the development reached the stage where the Minister of War, General Billot, decided to adopt it as a standard weapon

for the French army. Equiping the army with the new gun required an expenditure of 300,000,000 francs, and it had to be done with the utmost secrecy. Very few persons knew of the success of the new gun, and the general information permitted to filter through army circles was of the most pessimistic character. A series of complicated political and financial moves followed, the result being that the money was permitted to be spent with the utmost secrecy, and the first knowledge the world had of the new guns was when they began to be delivered to the artillery units. This was made possible by distributing the manufacture of parts among various government establishments and by a development of design and methods of gaging and checking of such high precision that all parts were absolutely interchangeable. It need hardly be said that in 1896 to 1898 this was a radical departure from the usual methods of manufacture followed in Europe.

While all this was being done strenuous efforts were being exerted in the development of the Ducros gun, a weapon of 90 mm. bore and having no brake. Numerous tests of this gun were made by commissions of imposing appearance and a veil of secrecy thrown around it, but care was taken, nevertheless, that sufficient information regarding it should drift across the Rhine. In this way German military circles were led to believe that it would be the Ducros gun that the French army would adopt. To meet this emergency they started to build at a tremendous rate their own 77-mm. gun, which they justly considered to be superior to the Ducros gun. The 77-mm. gun, however, had not been sufficiently studied, and when the test came in 1914 proved to be inferior to the French 75. (*La Nature*, no. 2752, Jan. 1, 1927, pp. 41–42, *g*)

Timing Valve to Assure Tight Rivets

Automatic control of the time during which the full tonnage of a riveter remains on a rivet after it has been driven is the function of the timing valve, which has been brought out by the Hanna Engineering Works, 1765 Elston Avenue, Chicago. The device is intended to eliminate the human element as a factor affecting the quality of rivets driven hot in a compression-type riveter and therefore assure uniformity of the product.

In driving rivets, particularly of boiler quality, the full tonnage of the riveter is maintained on the rivet after its driven head is formed, until the rivet cools sufficiently to recover its full cold strength, fill the hole, and grip the plates tightly. The time for adequate cooling under die pressure will vary with the diameter and length of the rivet, and each riveting job is likely, therefore, to require a different timing or dwell period. This can at least be merely an approximation when complete reliance is placed upon the operator's judgment of what constitutes the proper dwell period.

It has been found that when the dwell period was uniform, tight rivets were obtained with a dwell of 10 sec. where 15 sec. had formerly been the standard without the timing mechanism. It is claimed that in this instance the percentage of loose rivets was reduced to nil, an increase in production of 50 per cent resulted, and the cost of cutting out and redriving rivets was almost eliminated.

The timing valve, it will be seen, permits of accurately determining the dwell period which will insure tight rivets for each riveting job, and after being set the valve assures sufficient dwell upon the rivet. The dwell valve operates as follows: The operator depresses the valve handle, whereupon the rivet die advances on the rivet. When each rivet is 50 per cent driven the valve goes beyond the control of the operator, and the riveter finishes and dwells on the rivet for the predetermined period, at the expiration of which the valve reverses automatically returning the riveter mechanism to its starting position. The valve may be reversed manually as the rivet die is advancing, prior to the rivet die striking the rivet. This constitutes an important safety feature. The valve may be set or adjusted for any duration of dwell from 1 to 60 sec., which setting is by direct reading and requires no trials. Once set, the valve may be sealed and cannot be tampered with without breaking the padlock seal. Therefore riveting operations may be placed on a piece-work or bonus basis without jeopardizing the quality of the work. The valve may be placed at any point for convenient operation as it is a self contained unit.

The timing element is a constant-speed fractional-horsepower motor with gear reduction and can be arranged for either alternating or direct current of any voltage. *The Iron Age*, vol. 119, no. 5, February 3, 1927, p. 363.

WELDING

Thermal Disturbance in Iron and Steel During Welding

The thermal processes considered by the author are thermit welding, resistance welding, oxyacetylene welding, carbon-arc welding, and iron-arc welding, but not blacksmith welding. The types of disturbance are grouped according to their characteristics, as follows: (1) Alteration in grain size; (2) modification of disposition of the constituents of the original metal; (3) alteration of the chemical composition of the metal at this junction; (4) junction characteristics between parent metal and parent metal in resistance welding, and weld metal and parent metal in other forms of welding.

Alteration in Grain Size. It is an unfortunate fact that continued heating of steels of low carbon content at temperatures between 600 and 900 deg. cent. will result in an increase in the size of the crystal grains of which the metal is composed, and within certain limits the longer this heating is carried on the larger the final size of the metal grains. The effect of increasing size is to reduce the ductility of the metal under treatment.

In this connection it is of interest to note that severe cases of grain growth on certain welds made in a resistance-welding machine were traced to the fact that small angle bars which were being welded together were first of all straightened and freed from scale by stretching them, until a considerable elongation took place, in a special machine.

A modified form of butt-welding consists in heating the metal to a much higher temperature in the welding machine, and then squeezing out a comparatively large quantity of the partly fused metal at the junction. The higher temperatures thus reached undoubtedly prevent excessive grain growth.

Oxyacetylene welds and electric-arc welds are prone to the same disease as welds made by the resistance process when highly stressed material is being operated on. The fact that the metal in an electric weld is generally deposited in several layers, one on top of the other, however, gives the effect of constant reheating and minimizes to a certain extent the troubles which are likely to be caused by producing a refining of the grain.

Alteration of Composition at the Weld Junction. This generally takes the form of decarbonization due to atmospheric oxidation, or to oxidized weld metal falling on the surface itself, commonest in resistance welds and in acetylene welds in which an oxidizing flame has been used to fuse the surface.

In welding steels containing 0.5 per cent of carbon or more in butt-welding machines, a certain amount of oxidation of carbon takes place at the junction and a thin line of decarbonized metal very often marks the line of weld; this in itself is quite harmless, except where high tensile strengths are expected. With low-carbon steels, however, it may and does often indicate an oxidized state of the weld metal, and hence a dangerous condition in the material.

It is quite frequently found that resistance welds in wrought iron or in steels with less than 0.1 per cent of carbon fracture across the weld for no apparent reason. The microstructure appears to be good and the tensile strength of the weld is excellent, but severe shock will cause immediate fracture. An undoubted cure for this trouble is to increase the carbon content of the metal to be welded, and there is no doubt that a great many of the failures which occur with resistance-welding processes are due to the fact that the composition of the steel is not suitable to the process.

There is no valid reason why steels of special composition should not be developed and marketed especially for resistance-welding processes. The demand is very great and would become enormously greater if a reliable and certain junction were assured with ordinary care.

Junction Characteristics. The characteristics of the junction between parent metal and weld metal are of the utmost importance, and it is unfortunate that so little attention has been paid to this subject.

There is no doubt that surface-tension effects come very strongly into play during welding, and as there is no pressure applied in any

process but resistance welding, differences in the surface tension of the molten parent metal and the molten added metal will sometimes result in the production of a sharp dividing line between the two.

Practical experiment, at present unsupported by any scientific work, goes to show that the presence of some elements in the parent metal greatly aggravates these surface-tension effects. Phosphorus and sulphur are both exceptionally noticeable in this respect, and there is no doubt that the difficulties attendant on the successful welding, by either arc or acetylene, of some cast iron and some wrought iron is due to the presence of excessive quantities of one or both of these elements. Just as certain conditions must be observed before one fluid can be made to "wet" another, or solder be made to "wet" the surface of copper or iron, so certain conditions can be brought about under which molten weld metal will flow evenly over the surface of a parent metal, even although it may contain deleterious components, and thus produce or help to produce an efficient junction.

It is a remarkable fact that one of the most efficient fluxes, if this term may be used, in the case of high-phosphorus or high-sulphur irons, is a metallic oxide, particularly of a metal of similar atomic weight to iron. Iron oxide itself is extremely efficient in this respect, but still better are the oxides of nickel or chromium. These may require the presence of some low-melting-point material to help them to flow properly and thus do their work, but they still remain the active ingredient of the flux.

In the discussion which followed, the author said that quite recently a well-known man in Germany had been doing resistance welding with hydrogen, with the idea of proving or disproving some of the theories propounded as the result of the brittle structure produced at the junction, because it was an extremely common phenomenon in some types of weld. The resistance welds in hydrogen had been found to be just as bad from the point of view of brittleness as welds in air. A good many phenomena of this type would depend on the purity of the hydrogen used, but the investigator claimed to have used pure hydrogen and to have gotten brittleness still, and suggested that if the brittleness were due to traces of oxygen, the oxygen might be in the hydrogen in quantities too small to be detected, but his (Dr. Paterson's) feeling was that there must be some other explanation than that. The question of the structure produced with a bare and a covered electrode was rather a remarkable one. When a bare electrode was employed, one used a lower voltage, and, with the same current strength, obtained a lower arc energy than when a covered electrode was used.

The Quasi-arc electrode, which was typical of the slag-coated electrodes, worked generally at about 25 volts, and that, with 100 amperes, would give 2500 watts, whereas the bare wire, with the same current strength, at 18 volts, would give 1800 watts at the arc. Therefore, with the same current strength one obtained more heat with the one than with the other; in other words, the metal required longer to cool. With a bare wire one could produce a columnar structure, but one might at the same time produce a very different state of affairs alongside. (J. H. Paterson, D.Sc., in a paper read November 29, 1926, before the Institution of Welding Engineers (Great Britain). Abstracted through *The Iron and Coal Trades Review*, vol. 113, no. 3066, Dec. 3, 1926, p. 848, *p*)

Cutting Metal Under Water

In this method heat is generated by means of an electric arc using a carbon electrode, in addition to which oxygen is introduced into the heated area in order to make a chemical combination with the steel in the same manner as happens in the case of an oxyacetylene flame used in ordinary (above-water) cutting operations.

The torch itself consists of a non-conductive handle with a shield in front of it to protect the hand of the operator from the heat of the arc. In front of the shield is the holder of the electrode with connection for the lead wire. There is also the connection for the oxygen hose to be attached to the torch. A flat carbon electrode, which has two holes longitudinally through its center, is used and set in the holder.

The two holes in the electrodes are at their posterior, and are connected to the hose from the oxygen bottle by means of the special connection. The cable and hose are connected together in one conduit. These, with the life line and air hose, complete the diver's underwater equipment.

The electric-current valves are 400 amperes to 1000 amperes, at 90 volts to 100 volts, depending on the condition under which the work is being done. It is desirable to have an absolutely constant potential under varying loads.

The cutting action of this torch may be described somewhat as follows:

The diver strikes an arc by first touching the end of his carbon to that point of the object where he wants to start cutting, and then withdraws it until he has a long electric arc between the end of the electrode and the metal to be cut. The heat from the arc causes a globe of vapor to form around the arc, which is further increased when the oxygen flowing through the carbon is projected on the surface of the melting steel. Apparent difficulties as a result of the conductivity of water are in this way eliminated.

The arc is constantly keeping this bubble or blanket of steam intact while the oxygen blows out any molten metal from the cut. The result is a remarkably clean cut which looks more like a cut with an oxyacetylene flame than it does like one with an electric arc.

There are considerable difficulties connected with the operation of the underwater cutting torch. The diver has a lot of apparatus to handle, has to take awkward positions to get at work, and is exposed to a certain amount of danger. In the winter he can only work a very short time before he becomes chilled. In dirty harbor water the visibility is practically nil. Special electric diving lamps have been designed to help the diver in working in muddy water and at great depths.

The original article describes several instances in which this process of underwater cutting has been successfully applied. (Wm. Schenstrom in the *Journal of the American Welding Society*, vol. 5, no. 3, March, 1926, pp. 55–57. Compare reprint in *Canadian Machinery and Manufacturing News*, vol. 37, no. 1, Jan. 6, 1927, pp. 27, 41 and 44, *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Industrial-Research Laboratories in the United States

The continuing demand for a new edition of Bulletin No. 16 of the National Research Council which contains a list of research laboratories in industrial establishments of the United States, indicates that this list apparently fills a certain need in the industrial world, and confronts us with the fact that the material assembled in 1921 is five years out of date and should be revised at this time.

It is undoubtedly true that since 1921 a large number of industrial concerns have established research laboratories. It is also probably true that the 1921 list does not contain a complete roster of the firms which had laboratories at that time. In order that the new list may be as complete as possible, the N.R.A. appeals to the readers of this journal who are connected with firms now maintaining research laboratories to send them a post card giving the name and address of the firms with which they are connected. Questionnaires will then be sent to these firms.

The value of such a compilation lies first in its accuracy; second, in its completeness. The completeness of this compilation can be assured only by the coöperation of those in immediate touch with the various laboratories which should be included.

Please address your post card to the Research Information Service, National Research Council, B & 21st Streets, Washington, D. C.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK, *Aeronautic Division*
H. W. BROOKS, *Fuels Division*
R. L. DAUGHERTY, *Hydraulic Division*
JAMES A. HALL, *Machine-Shop Practice Division*
CHARLES W. BEESE, *Management Division*
G. E. HAGEMANN, *Materials Handling Division*
J. L. WALSH, *National Defense Division*
L. H. MORRISON, *Oil and Gas Power Division*
W. R. ECKART, *Petroleum Division*
F. M. GIBSON and W. M. KEENAN, *Power Division*
WINFIELD S. HUSON, *Printing Machinery Division*
MARION B. RICHARDSON, *Railroad Division*
JAMES W. COX, JR., *Textile Division*
WM. BRAID WHITE, *Wood Industries Division*

Aeronautics

Motor Life, American and Foreign

A-11 How does the life of the American motor compare with that of the foreign motor in actual flying time (not bench tests)?

The writer can give no figures on this subject. However, long flights by the British aviator, Sir Allen Cobham, would indicate that some of the British engines are longer lived than American engines. (William A. Bevan, Assistant Professor of Mechanical Engineering, in Charge of Aeronautics, Purdue University.)

Airplanes for Commuter Service

A-12 What are the prospects of the employment in the near future of very large airplanes for the transportation of passengers in commuter service in the United States?

Ordinarily the term "commuter service" brings to mind a short haul. It seems to the writer that the big field for passenger transportation by airplane is in the long haul instead of the short haul, as the time actually saved by flying is lost unless the airport is in the heart of the city to which the commuting is done. Of course, there probably will be a certain amount of commuting done by air by means of flying boats to cities with water fronts. On the other hand, the operation of a flying boat is more expensive than that of the land type of machine, and for the same horsepower the pay load is less, due to the added weight of equipment for landing on the water. Therefore, it would seem to the writer that service of this nature is more or less limited. (C. S. Jones, Vice-President, Curtiss Flying Service, Inc., Garden City, L. I., N. Y.)

Prospects do not appear to the writer to be very promising. People of the United States are not yet "air minded." They consider flying very dangerous. Too many are interested in taking a flight for the thrill it affords, or to see "stunting." (William A. Bevan, Assistant Professor of Mechanical Engineering, in Charge of Aeronautics, Purdue University.)

Earnings of Contract Air-Mail Lines

A-13 Which of the contract air-mail lines are paying expenses and which are not?

As far as known to the writer, the only contract air-mail line which is now showing a real profit is the line operating between Salt Lake City and Los Angeles, due largely to the great saving of time and an unusual amount of airplane mail because of the film business. The National Air Transport Co., operating between Dallas and Chicago, is just about breaking even, and it is the writer's belief that most of the other lines are losing money. However, this is not considered discouraging, for no one with any knowledge of the subject thought the air mail could pay its way the first year. Furthermore, even though authorized under the Kelly bill, it has not been the practice of the Post Office Department to allow the contract air-mail lines to carry ordinary first-class mail, and the load has been restricted to special airplane mail. Because of the newness of the business, very few passengers have been carried and certain of the contract lines do not practice the transportation of passengers. However, as the lines increase in efficiency and the ships become more suitable, there probably will be quite a business in passenger carrying. Finally, the new arrangement with the American Railway Express Co., which permits the carrying of express packages, will bring an additional source of revenue, so that in the opinion of the writer any line that is efficiently operated and has a live traffic sales department should show profit within the next year. (C. S. Jones, Vice-President, Curtiss Flying Service, Inc., Garden City, L. I., N. Y.)

Fuels

Slagging in Boiler Furnaces

F-10 What has been done to correlate the fusion temperature of coal ash with slagging in boiler furnaces? Give specific data or references if possible.

The U. S. Bureau of Mines and others have attempted to devise a fusion test method which would enable purchasers to predict the clinkering tendencies of the ash of a given coal, but have been only partially successful. Engineering designs of boiler furnaces are now directed toward improvements which eliminate slagging difficulties in spite of the characteristics of the ash. (W. E. Caldwell, Assistant to General Superintendent of Power Plants, United Electric Light & Power Co., New York, N. Y.)

Considerable research work is now being done by manufacturers of equipment, public-utility companies and others, and work is also being carried on at the Mellon Institute, Pittsburgh, in connection with this subject. For further information, communicate with C. F. Hirshfeld, Research Department, Detroit Edison Co., asking for reports that have already been issued. (J. G. Worker, Assistant to President, American Engineering Company, Philadelphia, Pa.)

Moisture Content of Coal for Pulverizing

F-11 What maximum-moisture-content coals have been successfully and continuously burned in pulverized form in unit systems? Describe operating conditions encountered, furnaces employed, and results obtained.

This question cannot be answered definitely by the writer. Some coals containing 10 per cent moisture may be easily handled, while others give trouble with 5 per cent moisture. With excessive moisture the mill capacity is reduced, feeding difficulties are encountered, and operation is uncertain. (W. E. Caldwell, Assistant to the General Superintendent of Power Plants, United Electric Light & Power Co., New York, N. Y.)

The Union Electric Light and Power Company, Ashley Street Station, St. Louis, is pulverizing coals with 10 per cent moisture. Particulars regarding the operating conditions, furnace employed, etc., can be obtained from the National Electric Light Association Prime Movers Committee's Report of August, 1926. (J. G. Worker, Assistant to President, American Engineering Company, Philadelphia, Pa.)

Machine-Shop Practice

Machining Copper

MS-6 What lubricants and coolants should be used in machining pure copper?

An oil of approximately 150 seconds Saybolt at 100 deg. with 15 per cent of No. 1 lard oil. It is very important that the oil be neutral to organic and mineral acidity. Very pure lard oil is essential, otherwise corrosion is liable to take place, due to decomposition. (Arthur E. Pew, Jr., Chief Process Engineer, Sun Oil Co., Philadelphia, Pa.)

Precision Grinding of Copper

MS-7 How should pure copper be ground when fine precision in size is required?

For the accurate grinding of copper, it is of course assumed that a fine-grained wheel is used. Large quantities of clean water should be used to keep the work cool, but no lubrication is required. (Arthur E. Pew, Jr., Chief Process Engineer, Sun Oil Co., Philadelphia, Pa.)

Velocities Between Sliding Surfaces

MS-8 What are the present highest velocities between sliding surfaces in continuous service, and in what type of machinery? What is the nature of the material of which the surfaces are constructed? How is lubrication effected?

Probably the highest-velocity sliding bearings are the thrust bearings used in hydroelectric generators. These are of the Kingsbury type, that is to say, float pads which arrange themselves relatively to the thrust collar so that the oil film takes the natural wedge-shapes form. Lubrication should be effected by a highly refined oil or moderate viscosity, say, 150 seconds Saybolt at 100 deg., although of course the viscosity will vary considerably with the actual speeds and pressures. Speeds of course are also very high on some of the steam turbines of the horizontal type where precisely the same type of lubricant is required. (Arthur E. Pew, Jr., Chief Process Engineer, Sun Oil Co., Philadelphia, Pa.)

Welding Tool Steel

MS-9 What precautions are necessary in the welding of tool steels of various carbon contents? Is it necessary to provide special equipment for this work?

The most important precaution is to keep the air away from the steel as much as possible when it is being heated, thus preventing oxidation and burning. Special equipment most always tends to produce a more uniform quality and also increases production. (W. P. Turner, Professor of Practical Mechanical Engineering, Purdue University.)

Management

Position

MG-3 One often hears the expression "Position is everything in life." It is well known that position is very important in the industrial world, both as regards the relative position of the worker and the work, and the relationship of the foreman to the employee. Comments from members based on personal experiences or observations would prove interesting and valuable in endeavors to improve conditions in industry.

The position which is most vital to the worker is his own physical position in relation to his task or job. The great majority of the peoples of the earth are workers of some description, yet it is surprising to note how little attention is and has been paid to the relative position of the man to his work in many manufacturing institutions.

It has been the writer's good fortune to have been able to familiarize himself with existing conditions in several manufacturing plants engaged in various lines of work. Almost without exception there are numerous opportunities requiring little or no expenditure of money which will add materially to the personal comfort of the worker. Under proper supervision the result of lessening the worker's fatigue should be an increased production and consequent lower cost of manufacture.

In many instances a worker will have valuable qualifications, but simply due to the fact that he is compelled to go and get the work he is to do and later deliver it to some definite or indefinite place, the net result is that he is performing ordinary laborer's work during one-half of his day. If the work were brought to him and taken from him when he had completed his task, he would be subject to fewer interruptions and could give his undivided attention to the work for which he is primarily hired. In most localities it is possible to hire men for general trucking and laboring at rates below those of skilled or semi-skilled mechanics.

Not long ago the writer saw men dragging baskets along the floor to their work places. They then would bend over and toss the work up on to their benches by the handfuls. Upon completing their operations they tossed the work into baskets on the floor level. Then they dragged packing containers alongside, bent over to pick up parts from the basket, and while in the bent position packed the parts in the empty containers on the floor.

Knee-high movable iron stands placed in front of each work bench were given a trial. Each stand had space for an empty basket and space for a packing container. The work was thrown up on the work bench as before. When the work was done it was tossed into the empty basket on the stand—not down to the floor level as before. The empty packing container was then placed on the stand beside the basket now ready for inspecting and packing.

The result was that the bending over or "gymnastic time" of the worker was reduced by 70 per cent. It was plain to the eye that the men, in spite of the fact that they were day workers, were delivering more work than previously.

Some workers have ideas of their own as to how their tasks may be made easier. Others are hesitant about making their wants known through fear of creating in their superiors the impression that they are too "wise."

Many foremen and bosses have never associated with any other business or department aside from the one in which they are engaged. They often grow up in the business and do not visualize the advisability of a minor improvement here and there. They are like the famous general in a recent war who said that he was so close to the forest that he could not see it for the trees. Perspective is a matter of position. (G. W. Isbell, Industrial Engineer, Chas. E. Bedaux Co., New York, N. Y.)

Textile

Building Construction[1]

T-9 Why do textile manufacturers seem to favor buildings of slow-burning construction rather than of concrete?

Concrete construction is very stiff and rigid, and many of the machines used in the textile industry run smoother when they are installed on more elastic foundations. The so-called "slow-burning" construction is used almost universally, because of the fact that in certain departments of the mill a fire, once allowed to get beyond control, will warp or destroy a heavy concrete structure fully as quickly as it will the slow-burning structure. As a general rule, a fire in a slow-burning structure can be reached more easily by the fire fighters. This was well illustrated in the fires at the Naumkeag Steam Cotton Co. some years ago, and in one or two of the fires which have started in some of the large textile plants. (Edwin H. Marble, President, Curtis & Marble Machine Co., Worcester, Mass.)

Textile manufacturers favor buildings of slow-burning construction rather than concrete because they are cheaper to build; insurance rates are not as favorable to concrete as might be expected; they are more flexible for shifting machines; they can be built to allow as good lighting as concrete buildings; and, finally, because it is less expensive to hang shafting in them than in concrete structures. (Henry M. Burke, Plant Engineer, Mount Hope Finishing Co., North Dighton, Mass.)

[1] This subject has been discussed in a previous issue.

Engineering and Industrial Standardization

Proposed Standardization of Speeds of Driven Machines

UNDER present conditions the curve of the speeds of driven machinery is practically a random distribution without any logical ordering of the values used. As a result, the sizes of pulleys, gears, sprockets, etc., which manufacturers have to produce and which manufacturers, jobbers, dealers, and users must keep in stock, have been multiplied almost endlessly.

While the need for standardization and simplification of driving and driven connections has been apparent for years, particularly to producers of electric motors, steam engines, etc., nothing has been accomplished, because without coördination and standardization of the speeds of driven and driving machinery considered together, no satisfactory solution can be obtained.

The National Electrical Manufacturers' Association has requested the American Engineering Standards Committee to undertake the general standardization of the speeds of driven machinery. In making this request the association expressed a full appreciation of the magnitude of the difficulties involved. However, it believes that the economic advantages to the general public will be enormously greater than the trouble and expense involved in bringing about this standardization.

If this proposed coördinated standardization can be carried out, it will afford a very natural and easy approach to the problem of standardization and simplification of pulleys, gears, sprockets, etc. Furthermore, a simple, systematic series of speeds will introduce much greater flexibility in the selection and use of both power units and driven machinery. Interchangeability of units will be greatly promoted thereby.

Through such standardization, great economies will result to the manufacturers of power machinery and driven machinery, and to the innumerable industries dependent upon their use.

National Safety Council Finds Most Accidents Occur in Small Shops

THAT thousands of small shops, factories, and industrial establishments are making no real effort to conserve the lives and limbs of their employees is the belief of W. Dean Keefer, director of the industrial division of the National Safety Council.

A survey made by special investigators representing that accident-prevention institution discloses that small workshops have more accidents than larger establishments. For instance, a group of ten factories with a total of 1000 workers has a worse accident record than one large plant with the same number of employees.

Analysis of the reports received from the investigators, who visited 299 small plants in Michigan, Illinois, Indiana, Kentucky, Ohio, and Rhode Island, reveals the following fundamental unfavorable facts:

The only records that are kept of accidents that occur in small plants appear to be those made out for the insurance companies and state officials. The average small-plant executive declares and actually believes he has no accidents in his plant. He is too busy to pay any attention to accident prevention.

Small plants pay their compensation-insurance premiums and, after complying with the demands of the insurance companies and state officials, assume they have no further responsibility to safeguard their employees.

These executives do not realize that accidents cost them approximately four times as much as they cost the insurance carriers.

As a result of the facts brought out by the inquiry, which is believed to reflect the situation throughout the country, the National Safety Council is going to launch a campaign to interest particularly small plants in organized accident-prevention activities. Efforts will be made to induce small-plant owners and executives to keep and analyze records of their accidents. The council has prepared a comprehensive program designed especially for the proprietors and managers of small factories, workshops, and industrial establishments, details of which may be secured, free of charge, by addressing the council, which has headquarters in Chicago.

A Standard Invoice Form

IN CONNECTION with their program for the year, the National Association of Purchasing Agents (Inc.) will concentrate on a "drive" to accelerate the adoption of the National Standard Invoice Form. The Committee on National Standard Invoice Form will consist of one district chairman for each district, the national secretary acting as chairman of this national committee. Each district chairman will supervise the work of the various local committees in his district so as to tie them together into a single working unit, thus securing for all the benefits of the good ideas of each association. Duplication will thus be avoided, and the method of securing adoption of the national standard invoice form will be standardized. The editors of association magazines and bulletins, the invoice chairmen of affiliated associations, and others have been asked to assist in the drive by running articles and advertisements in their publications.

More than 80 nationally known trade associations have already indorsed the form. Thousands of corporations and a majority of the large railroad systems throughout the country are demanding its use. Following this, the comptroller general of the United States has requested all Government vendors to bill on the national standard invoice form.

Some of the principal advantages of a standard invoice form are that it eliminates misunderstandings and inconveniences; expedites shipments and the settlements of accounts; saves money by reducing clerical personnel; saves paper by cutting from standard-size stock without waste; saves correspondence by including all necessary information on the forms themselves; saves time in filing, finding, and handling while being checked; and saves filing space through uniformity of size, etc.

Proposed Revision of Classification of Industries in Standard Plan for Accident Statistics

THE National Conference on Industrial Accident Prevention at its annual convention held in Washington, D. C., in July, and the International Association of Industrial Accident Boards and Commissions at its annual convention held in Hartford, Conn., in September, both passed unanimously resolutions calling on the American Engineering Standards Committee to authorize the formation of a Sectional Committee under the sponsorship of the I.A.I.A.B.C. to revise the classification of industries in the standard plan for accident statistics of that association, and also to consider possible revision of other features of that plan, with a view to making it adaptable to the needs of individual plants or firms for keeping of their accident records and compiling their individual experience.

The following fundamental considerations support this proposal:

1 Accident prevention is coming more and more to be recognized as a necessary part of the industrial-engineering work of each plant or firm.

2 An indispensable tool of accident prevention is properly compiled accident statistics, which may be regarded as the accounting factor of safety engineering.

3 Accident statistics are first of all a need of the individual plant or firm.

4 To fill that need adequately, however, the individual firm must not only have its own record but must have it in a form comparable with that of other firms and comparable with combined records for industries or geographical divisions which will afford base lines, so to speak, by which the individual unit in accident prevention, the plant or firm, may appraise its own experience.

5 To sum up in a word, accident statistics are essentially one of the engineering tools of industry, but as such require to be uniform according to some standard plan.

At the National Conference on Industrial Accident Prevention held in Washington in July, 1926, under the auspices of the U. S.

Department of Labor, the general subject of discussion was the Value of Statistics for Accident Prevention. Among others, a Committee on Classification of Industries (for use in connection with accident statistics) was appointed. This Committee consisted of six members, four of whom, including the chairman, were members of the Committee on Statistics of the Association. The other two represented respectively the National Safety Council and the National Council on Workmen's Compensation Insurance. As soon as this committee began consideration of its problem, it realized that the first question it was called on to decide was whether or not the standard industry classification of the Association needed revision, and, if so, how such revision could be best carried out. This question soon broadened also into that of whether, after ten years of experience under it, the entire standard plan for accident statistics of the Association should not now be restudied with a view to revision in the light of experience and recent developments in industry, accident prevention and statistics. The result was that the National Conference Committee reported unanimously:

1 That some revision of the existing plan for standard and uniform accident statistics of the International Association of Industrial Accident Boards and Commissions seems desirable;

2 That such a revision is a matter requiring study and time;

3 That pending such a revision the use of the existing plan is urged;

4 That the most promising means of revision would be utilization of the machinery of the American Engineering Standards Committee, as it is being employed for development of standard industrial-safety-code rules;

5 That the logical and appropriate agency to sponsor revision by this means would be the International Association of Industrial Accident Boards and Commissions under whose auspices the existing plan was developed.

The Committee therefore recommended:

That this Committee be temporarily continued and authorized to take up negotiations with the International Association of Industrial Accident Boards and Commissions and the American Engineering Standards Committee looking to revision of the standard plan by this means.

This report was adopted by the Washington Conference and presented to the Convention of International Association of Industrial Accident Boards and Commissions at Hartford, Conn., in September, with the result indicated above.

At its meeting on October 14, 1926, the American Engineering Standards Committee referred the request to a committee for study and recommendation.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

The Strength of Gear Teeth

To the Editor:

Referring to the letter by A. L. Kimball, Jr., published in the January issue of Mechanical Engineering (p. 63), we agree that mention should have been made by us of previous applications of the photoelastic method to the gear problem in our publication. However, we do not agree with Mr. Kimball's statement that his work "almost exactly covers part of our studies" on the strength of gear teeth. The paper on Stress in Electric-Railway Motor Pinions, by Messrs. Kimball and Heymans, to which he refers, was published in Mechanical Engineering, February, 1923, p. 93, and was discussed in detail by one of us at that time (see same issue, p. 137).

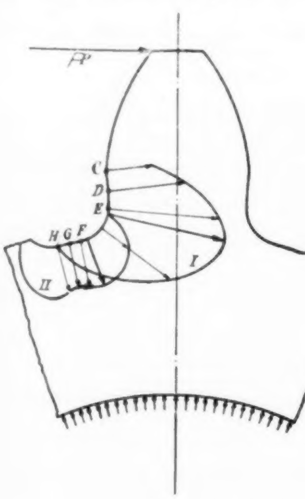


Fig. 1

In this discussion it was explained that the results of Messrs. Kimball and Heymans cannot be directly applied in calculating gear-tooth stresses because the load conditions in their work were not well defined and the effect of variation of fillet radius at the tooth root on the stress concentration was not studied. Having in mind these two important points a new series of tests was made by us, which work resulted in a simple formula giving a direct comparison of actual stresses with the simple beam-theory stresses. Furthermore this formula may be directly applied in practical problems.

It should be noted also that the paper of Messrs. Kimball and Heymans was not the first publication on the application of the photoelastic method to the study of stress distribution in gear teeth, because Prof. E. G. Coker in his paper "La Photo-Elasticimétrie (Memoires de la Société des Ingénieurs Civils de France, Bulletin de Juillet, September, 1922), mentions the work done in his laboratory at University College, London, along this line, and gives curves of principal stresses and stress distribution along the tooth-root fillet.

Referring now to the remark of Mr. Kimball concerning the effect of shrink-fit pressures, we stated in our paper (see Mechanical Engineering, November, 1926, p. 1108), "that the stresses due to shrink-fit pressure do not appreciably affect the maximum stresses produced by bending of the tooth." In making this statement we had in mind the fact that the stress due to shrink-fit pressure becomes zero at a point where the stress set up by bending of the tooth is a maximum, as will be seen from Fig. 1, in which curve I represents bending stresses and curve II shrink-fit stresses. The above statement does not mean, however, that the sum of the two stresses at other points along the edge is always less than the maximum stress due to bending alone. Neither does it mean that, under certain conditions, some higher stresses than those at the tooth root could not be produced at the bore of the pinion by high shrink-fit pressures. We consider these points important for designers and are continuing the photoelastic work in this direction.

S. Timoshenko[1]
R. V. Baud.[2]

East Pittsburgh, Pa.

To the Editor:

I have read the letter by Mr. R. V. Baud on The Strength of Gear Teeth, in answer to my letter in the January issue of Mechanical Engineering, and note that exception is taken to my statement that Mr. Baud's and Dr. Timoshenko's work "almost exactly covers part of our studies." Nevertheless it is difficult for me to feel that it is not essentially true, since in both cases a quantitative study was made of stress distributions in gear teeth for different torques, different mounting pressures, and different tooth designs by using the photoelastic method. (See p. 521 of our paper in Trans. A.S.M.E., vol. 44.)

A more complete discussion of our results, however, with application to design formulas would have been very useful. In this

[1] Engineer, Research Department, Westinghouse Electric & Manufacturing Company. Mem. A.S.M.E.

[2] Engineer, Research Department, Westinghouse Electric & Manufacturing Company.

regard Mr. Baud and Dr. Timoshenko are to be congratulated, and also because they have carried the work much further in the way of obtaining design data.

I am glad to have Dr. Coker's paper called to my attention. It should certainly have been mentioned.

Regarding the effect of shrink pressures, if the curves in the figure accompanying Mr. Baud's letter be superimposed, a resultant curve is obtained which is very similar to that of Fig. 16, page 529, of our paper, which shows the results of an analysis of the same thing, as does also Fig. 20, page 534, under slightly different loading conditions. The curves showing each effect separately are nevertheless interesting.

I should like again to call attention to some impact tests on pinions made by us, described briefly in Transactions of the American Society for Steel Treating, 1924, pages 509–514, which may be of use in further study of this problem. The subject of shrink fits is an important one and further work as mentioned by Mr. Baud should be of value, and I shall be much interested to see the results.

A. L. Kimball, Jr.[3]

Schenectady, N. Y.

The Change of Viewpoint of the Machine Shop

To the Editor:

The viewpoint taken by A. L. DeLeeuw in his paper The Change of Viewpoint of the Machine Shop (Mechanical Engineering, January, 1927, p. 37), differs greatly from my own. I would therefore like to express my ideas upon the turning away of machine-shop practice from purely individual skill and experience to well-founded theory, and its gradual change from an art to a science.

By "art" I mean the power of doing something not taught by nature or instinct. Art proposes and defines an end, and turns it over to science. Science, after investigating causes and conditions, returns it to art with a combination of circumstances under which the end may be attained. Art then pronounces whether any or all of these scientific combinations are possible by human means.

In view of these facts I do not see how machine-shop practice can go on without both art and science—I do not see how skill and experience can be eliminated.

"Transfer of thought or intelligence" from a person to a machine is possible, as for instance in the case of the ordinary drill jig. With such a jig an unskilled person can drill as accurately spaced holes in duplicate parts as the most skilled workman can without it.

Thus because of what has aptly been called the "transfer of skill," accuracy no longer depends on the skill of an operator but rather upon the accuracy of his tools. It is evident that the more the skill that is transferred to a machine, the less that is required of the operator. This brings us face to face with the fact that individual experience, skill, art, and science are very important factors in the making of the machine.

Why, then, is it true that when the experienced drill-press operator is off for a day, some other workman with the same machine and the same jigs will never drill nearly as many parts as the experienced operator? It is because the new man does not possess the skill, experience, art, and science of quickly and accurately placing the parts in the jig, setting the jig, and skilfully manipulating the machine.

It is absurd, then, to say that there is no art in the operation of a drilling machine using jigs. It is therefore absurd to say that a machine shop can be operated with inexperienced and unskilled workmen.

Many mechanical-engineering graduates have the mistaken idea that shopmen are obstinate and narrow. Many shopmen, on the other hand are prone to criticize severely the young engineer in his machine-shop-practice work.

In spite of the fact that the average shopman never had an opportunity to attend college and very likely stopped learning when he had acquired the necessary knowledge and skill to command a living wage, he takes a natural pride in the skill and art acquired through years of actual practice. It is human nature for such a practical shopman to be quick to criticize the junior engineer who attempts to fill the position of a full-fledged mechanical engineer. However technical the young engineer may be, he generally lacks something of extreme importance, that something being practical experience.

The proper discharge of the duties of the modern machine shop in almost every instance demands both technical ability and practical experience. A strictly technical man as mechanical engineer of such a shop finds it extremely hard sailing when it comes to dealing with the practical men and practical problems in a practical way. The reason for the wide gap between him and the practical men is his lack of practical experience.

The world needs many more skilled mechanics than it does engineers. While it may not be necessary for all these skilled mechanics to have technical training, it is of the utmost importance that a mechanical engineer in addition to his technical training should be practically mechanical.

The commanding position of the United States is largely due to her machinists, who by their special tools and labor-saving machinery have brought into being our locomotives, automobiles, bridges, skyscrapers, etc., and who have enabled us to compete successfully with foreign manufacturers. Few trades or professions require such intelligence, such study, such close application, such common sense, and such surgeon's delicacy of touch as that of the machinist. His work ranges from a needle to a battleship, and he deals in limits of accuracy as close as the millionth of the inch.

When mechanical-engineering education advances to the point where every student must have enough credits in actual machine-shop practice for him to be graduated as a machinist as well as an engineer, then, and only then, will shopmen and mechanical engineers experience the meeting of minds which comes from mutual understanding.

Arthur D. Marcotte.[4]

Memphis, Tenn.

A.S.M.E. Boiler Code Committee Work

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

Revisions and Addenda to Boiler Construction Code

It is the policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision in the Rules in its Codes. Any suggestions for revisions or modifications

CERTIFICATE OF SHOP INSPECTION

Insurance Company's Serial Number............

VESSEL MADE BY......................at......................

I, the undersigned, holding a certificate of competency as an inspector of steam boilers in THE STATE OF...................., and employed by the..........................of......................, inspected internally and externally, the vessel specified in this report, on............

..........19 , and certify that the statements made on this report are correct, corresponding with the mill test reports of material as furnished by the builders, and measurements made of the vessel when completed; and that this vessel is constructed in accordance with the A.S.M.E. Boiler Code Rules for the Construction of Unfired Pressure Vessels.

....

Inspector of Boilers for State or Boiler Insurance Company

[3] Research Engineer, General Electric Co. Assoc. A.S.M.E.

[4] In Charge of Machine Shop, U. S. Engineer Depot, War Department, Assoc-Mem. A.S.M.E.

that are approved by the Committee will be recommended for addenda to the Code, to be included later on in the proper place in the Code.

The Boiler Code Committee has recently received and acted upon a suggested new Manufacturers' Data Report for Unfired Pressure Vessels which has been approved for publication as addenda to Section VIII of the Code. This form is published below and is submitted for criticisms and comment thereon from any one interested therein. Discussions should be mailed to C. W. Obert, Secretary to the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Boiler Code Committee for consideration.

After 30 days have elapsed following this publication, which will afford full opportunity for such criticism and comment upon the form as approved by the Committee, it is the intention of the Committee to present these addenda as finally agreed upon to the Council of the Society for approval as an addition to the Boiler Construction Code.

MANUFACTURERS' DATA REPORT FOR UNFIRED PRESSURE VESSELS

As Required by the Provisions of the A.S.M.E. Code Rules

1. Manufactured by .... (Name and address of the manufacturer) ....

2. Manufactured for .... (Name and address of the purchaser) ....

3. Type .... (Horizontal or Vertical) Unfired Pressure Vessel No. (........) (Registered No.) (........) (Mfrs.' serial, or A.S.M.E. No.) (........) (State and State No.) Year built ....

4. Have mill test reports been checked on all the plates entering this unfired pressure vessel ....

   Do the chemical and physical properties of all plates meet the requirements of the Code ....

5. Shell or Drums: No. .... Diameter .... ft. .... in. (or width) Length over all .... ft. .... in. Height .... ft. .... in.

6. Stamps on shell plates .... (Brand and lowest tensile strength) Rivets, stays and braces .... (Iron or steel)

7. Shell Plates .... in. (Outer) (Thickness) Butt straps .... in. (Thickness) Style of seams: Longitudinal .... Girth .... (Riveted, Forge Welded, Brazed, or Fusion Welded—Type of)

8. Diameter of rivet holes .... in. Pitch of rivets .... X .... X .... Efficiency of joint .... %

9. Girth Joints .... (Single or double riveted) Diameter rivet holes .... in. Pitch of rivets .... in. No. of courses ....

10. Inner Shell .... in. (Thickness) Style of seams: Longitudinal .... Girth .... (Riveted, Forge Welded, Brazed, or Fusion Welded—Type of) Length of section or course .... ft. .... in.

11. Heads: flat or dished .... in. (Thickness) Radius of dish .... in. Side to pressure .... (Concave or convex)

    If removable, bolts used .... (Number and size) or method of fastening .... (describe or sketch)

12. Stays:

Stays	No.	Size	Net area	Welded or weldless	Area to be stayed	Maximum allowable working pressure
(a) F. H.	....	....	....	....	....	....
(b) R. H.	....	....	....	....	....	....
(c) Through	....	....	....	....	....	....
(d) Diagonal and Gusset Stays	....	....	....	....	....	....

13. Staybolts .... (Iron or Steel) If hollow .... (Size of hole)

14. Maximum pitch .... (Horizontal) X .... (Vertical) Diameter .... in. (Over the threads)

15. Safety Valve outlets: No. ...., Size ....

16. Fusible Plug (if used): No. .... Diameter and material of filling .... Location ....

17. Outlets: No. .... Size .... Material of nozzle or reinforcement .... How attached .... (Riveted—Welded)

18. Drain connection .... in. (Size) Hand Holes or Sight Holes .... (Number, size, and location)

19. Manholes: .... (Number) .... (Size and location of each) Reinforcement .... (Riveted, Welded, etc.)

20. Method of supporting vessel ....

21. Bursting pressure .... lb. per sq. in. Hydrostatic test .... lb.

22. Maximum pressure .... lb. per sq. in. Unit stress ....

Remarks: .... (Vessel to be used for air, gas, ammonia, etc.)

....

....

We certify the above data to be correct and that all details of material and construction and workmanship on this unfired pressure vessel conform to the A.S.M.E. Unfired Pressure Vessel Code.

Date .... 19 .... Signed .... (Manufacturer) by ....

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

The Confidence of Coöperation

THERE has come to our attention the story of a sales conference in which the members of a force of a certain concern were pitted against each other. Each district manager was given the problem of selling one competitor's product to the head of the firm before the assembled salesmen; not exactly *carrying* coals to Newcastle but *selling* coals to Newcastle. The salesmen quite naturally found themselves in the position of an attorney for the prosecution who discovers himself defending the accused. An intimate knowledge of the competitor's product, and a ruthless comparison of it with their own, became necessary. And so, the story runs, one salesman spent two days at the competitor's factory, at the competitor's invitation, inspecting its manufacturing methods and product.

The moral of the story is not that herein lies a method of training salesmen, nor that to steal like Ulysses into the Trojan camp will inform one of the secrets of his opponent; for this man went not as a spy unknown to the competitor, but in his true capacity of rival salesman. It is, rather, that contact made through membership on A.S.M.E. committees had given the heads of these competing concerns so wholesome a respect for each other that they had ceased to consider themselves antagonists. The spirit of working together for the common good spread out from the committee room and enveloped the factory. Through the medium of mutual interest in Society affairs was born a mutual interest in commercial life. Had this relationship never been established, the story would never have been told. The fallacy of secrecy in this industry has been exploded.

Better Technical Meetings

PAPERS on important topics, well written, well presented, and well discussed, are the essentials of good technical meetings. The holding of such meetings is an important function of an engineering society. They do not need to be confined to sessions of a great annual convocation, but may be successfully held at local centers as recent experiences at Cleveland, Chicago, Philadelphia, and New York have proved.

The value of a meeting depends solely on the purpose that actuates it. If it is set up on a high plane with the desire to accomplish a worth-while purpose and plans are made accordingly, it will be a success. Holding a meeting merely for the sake of holding a meeting is unworthy of an engineering society.

One important detail is the manner of presenting papers. In this, local sections and local societies can do much by insisting on proper preparation by the authors. An engineer who presents a paper should not confine himself merely to reading his manuscript. He should know his subject-matter well enough to speak directly, forcefully, and interestingly. If he has something worth while saying, he should say it in a worth-while way. An engineer immersed in his technical specialty has little opportunity to face the public. His worth to himself, his employer, and his profession is increased if his appearance before his public and his engineering society is satisfactory. Presumably he knows his subject, but if he confines its presentation to the preparation of a written document he does himself and his hearers an injustice. If, however, he gives thought to the points that he should bring out, phrases them in an effective manner, rehearses his remarks before a mirror, and speaks to the last row of his hearers, he holds his audience and the meeting is worth while.

Foreign Eyes on American Industries

EUROPE seeks the secrets of American industrial success with all the instruments at her command. Her literature reflects her interest in American success and discusses the possibility of adopting American methods. American processes of mass production and marketing have been raised to the plane of philosophies and analyzed ponderously in the best metaphysical manner. Books, magazine articles, and newspaper stories written by visitors to the United States on the ethical, cultural, and material effects of American methods have been lavished on European readers, and her statesmen and industrialists are concerned with the lessons drawn.

Countless missions, official and unofficial, are streaming into the United States. They represent boards of trade and other similar public bodies, trade unions, bankers, the press, and individual manufacturing concerns. They come to secure first-hand information about labor relations, wages, working conditions, mass production, marketing methods, corporation structure, and the many factors peculiar to American industry which have increased the well-being of the workingman and brought prosperity to the stockholder. In turn, qualified missions and individuals from this country have been invited to Europe to aid in the analysis of troubles.

One mission which attracted public notice during its visit and whose findings have since received wide publicity, was the London *Daily Mail* Trade Union Mission which visited the United States about a year ago to discover the secret of high wages. Its report on the prevailing coöperation between workman and employer, the general acceptance of the principles of specialization and standardization utilized in mass production, and the broad acceptance of the importance of high rates of production by the maximum use of machinery, is an interesting and stimulating document.

In November, 1926, M. Ch. deFreminville (Hon. Mem. A.S.M.E.) published a translation of the salient portions of the *Daily Mail* Mission Report in the *Bulletin de la Société d'Encouragement pour L'Industrie Nationale*, of Paris. In his introductory remarks, M. deFreminville ascribes the development of sound industrial relations in this country to the work of Taylor. American industrial leaders, he writes, are looking ahead; they do not care particularly about the history of the principles they use in their daily tasks, and their origin may soon be forgotten. The remarkable development of American industry since the war is the result of putting into practice the fundamentals laid down by Taylor. This is more generally recognized by continental Europeans than by Englishmen or by Americans themselves. In a recent public discussion one Englishman took occasion to point out that a study of American industry would yield nothing to indicate the influence of Taylor. If he means that nothing is left of the details of printed forms adopted and installed by Taylor and his followers, he is probably right. Blank forms change rapidly, but the principles of Taylor are as sound today as they were when presented twenty years ago. An analysis of American industry will prove their influence on it.

The Educational Value of Power Shows

Specialization in manufacture applies to power as well as to the more tangible industrial products. In the early days it was not only customary but it was through force of circumstances that mills and factories were located beside streams. The decentralization of industry began with the general introduction of the steam engine, and with the introduction of electricity the manufacture of power became an industry in itself.

As one of the greatest of modern industries and as one upon all the others depend more than upon any other, it is very important that engineers and even the general public should have frequent opportunities of learning of the latest developments in the manufacture, transmission, and utilization of power. The great Power Shows which have grown up within the past few years are splendidly fulfilling this educational need, and full advantage should be taken of them by every engineer.

Specialization in power manufacture has naturally divorced a large body of the mechanical engineers from the direct consideration of the manufacture of power. All that they ask is that it be delivered to them in constantly increasing quantities as the demands of their machines become greater and greater. At the same time this very specialization has made power specialists of another body of mechanical engineers, and it is due to the uninterrupted and persistent concentration of these men that such strides have been made.

Engineers in general owe it to themselves and to these power specialists to give periodic consideration to the remarkable ingenuity which is being displayed in improving the reliability and efficiency of power plants, distribution systems, and equipment for power application. For graphic representation of abstruse processes and devices for carrying out these processes, the Power Shows excel. The ingenuity of the demonstrations rivals the ingenuity of the apparatus under consideration.

In addition to the general broadening influence upon the minds of mechanical engineers outside the power field, the Power Shows are of real economic value to them. Such engineers are sure to carry away many ideas for the better use of power in their factories, and for its better application to machines in the design of which they are concerned.

The Power Shows are also teaching great lessons in conservation by counteracting the tendency on the part of the public to simply take power for granted. By impressing forcefully the unrelenting struggle toward economy in the generation and transmission of power on the part of power engineers, power users are made to consider and to force economy in their use of power. What one engineer carefully conserves, another engineer will no longer wilfully waste.

Engineering "Fundamentalism"

To accomplish in four years an amount of study for which an arts college would devote five years seems to be the aim of most engineering schools, and because of this concentration of effort, says W. E. Wickenden, Director of Investigation of the Society for the Promotion of Engineering Education, methods of teaching have followed the task system, "with work materials elaborately organized, with work requirements broken down into a sequence of small-dimensioned work units, with day-to-day work assignments, and with output inspected continuously and in detail."[1] Undergraduate as well as graduate engineers will admit the arduous curriculum; and they are familiar with the type of instruction that is based largely on concrete problems to which definite answers are presumably possible. Much later engineering practice is of a similar nature, and as a training for this very sort of thing the method appeals to everybody as being a practical one. But as engineering contacts grow broader and the problems are less concrete, as their economic and social aspects become of greater importance, then perhaps the type of mind which can calculate the size of a beam, or a shaft, or a pipe, may fail to envisage the factors which cannot be stated in feet, and pounds, and seconds.

One hopes always to find a superman in an engineer. With a fundamental training in the knowledge and crafts of the material world, what is there that is impossible of attainment by the intellect which possesses these powerful tools? And yet against this person are directed the criticisms of the less technically educated that he has no culture, that he is one-sided in his development, that he lacks the perspective of the economist, the financier, the politician, the historian, the humanitarian, the philosopher; in short, that his education and opportunities have not contained a sufficient abundance of wisdom and experience for him to lay claim to supermanhood. His neighbors marvel at the control which he has over the forces of nature; but they are worried and perplexed over the economic, social, and political problems which his advances leave in their wake. It is charitable at this point to remember that the frailties of humanity extend to engineers. Let us not expect too much, even of the engineer.

But to advance, we must add to the already overcrowded curriculum of the engineering student non-engineering courses which will make him a broader citizen and decrease the criticism of one-sidedness and mediocrity which is heard of him. And to this we must also add the training in fields of knowledge which are ever widening with the advances of engineering. With such accumulations, where shall we end? Undoubtedly we shall come back closer to fundamentals, both of subject and of method of study. We shall engage the mind of our students with problems of a fundamental nature, and we shall teach them to use reason as adeptly as the slide rule. Few educators will know how to handle this more difficult method of instruction, but those few will train engineers, not technicians; citizens, not inhabitants.

[1] The Investigation of Engineering Education, Sigma Xi Quarterly, vol. 14, no. 4, December, 1926.

Continental Aircraft Engines

It is obviously true that a means of transportation is worth while only if it is capable of completing its journey. The automobile did not develop to this stage until the sight of a motor car drawn by a four-legged "hay engine" ceased to be a familiar sight on the national highways.

Notwithstanding the fact that aviation is already more than quarter of a century old, it is only quite recently that a practical approach has been made to a solution of the problem of reliability of aircraft transportation. From a commercial point of view it is not at all encouraging to read for two or three months that a certain air voyage is to be undertaken, and then to be informed that the date has been deferred on account of some engine trouble; and later to have the start blazoned across the front page of newspapers in the morning, only to hear in the evening that the plane which started so bravely came down because a cylinder burned out or an oil pipe burst or some other part misbehaved.

Recent information coming from Europe would indicate that over there they are gradually getting this situation in hand. More and more trips are being made in which no engine trouble develops, and in fact a condition is gradually being reached where engine trouble in flying will be as it should be, an exception rather than the rule.

A number of long-distance flights without landing have been carried out in the past year by French officers. In June, Arrachart flew from a field in the neighborhood of Paris—from which all other French long-distance flights have been made—to Bassorah in Mesopotamia, a distance of about 2500 miles, with a Renault 550-hp. motor. In the next month Girier flew to Omsk in Siberia, roughly 2900 miles. This record was beaten by Challe with a flight to the Gulf of Persia which covered a distance of 3100 miles, and again by Costes with a Hispano-Suiza 500-hp. motor in a flight to Djask on the Sea of Orman and a distance of 3300 miles. Several other flights in excess of 2500 miles were also made by other officers. Three makes of French motors, Renault, Hispano-Suiza, and Farman, were used in these flights without any trouble developing. Further, a number of extremely long flights with short stops were made. One such flight was from Paris to Siberia and back, over 6000 miles; another, of about the same length, from Paris to various points in Africa; and a third, over India, of about 2200 miles. The remarkable thing about all of these flights is that each was made with the same engine from start to finish, and that at the end the engine seemed to be in remarkably decent shape. So much for what the French are doing.

A Berlin correspondent in the London *Morning Post*, Nov. 29 to Dec. 4, tells how Germany takes to the air (reprinted in *The Living Age*, Feb. 1, 1927), and emphasizes the high state of reliability already attained by German engines. A line is projected from Munich to Milan which will require flying over the Alps. When Major Hailer, manager of the South German Luft-Hansa, was asked, "What will happen if you have to make a forced landing over the Alps?" he replied, "That will not happen; we have faith in our machines." The amazing absence of accidents or forced landings in German flying would indicate that this faith in the machines is well justified.

The state of reliability attained by British machines is well illustrated by the long-distance flights that they have made. Some years ago a flight was made in less than 30 days from London to Australia under extremely trying conditions, but without any serious replacements to the Rolls-Royce motors with which the start was made from London. Since then Sir Alan Cobham has made several remarkable flights from London to India and back, London to Cairo to Cape and back, and London to Australia, in each of which no motor changes were made, notwithstanding the fact that some of the flights were well in excess of 20,000 miles. In the recent flight by the Secretary for Air of Great Britain and Lady Hoare from London to India, an attempt was made to adhere to a time schedule, which, of course, required that the motors should perform perfectly. The report is that the only difficulty experienced was not to arrive at various places ahead of schedule, and thus upset the various reception arrangements. Quite recently a flight was made by Lieutenant Bernard on a Lioré et Olivier flying boat with a 420-hp. Gnome-Rhone-Jupiter engine from Paris to Madagascar and back. This was an unusually hazardous and difficult flight because of its length (17,000 miles), because of flying through tropical countries, and finally because of the fact that an overland flight of great length was made with a flying boat. Of course, an attempt was made to follow rivers. Nevertheless the plane must have passed many stretches where a forced landing would spell disaster. However, the motor performed perfectly and gave no trouble whatsoever.

There is therefore every reason to believe that the airplane engine in Europe has already reached a very high stage of reliability, and this naturally is a matter of very great promise for the whole art of aviation.

Unusual Vacation Possibilities of White Sulphur Springs Meeting

IT IS ENTIRELY feasible to combine "business with pleasure" in an engineering society meeting by holding such a meeting at a pleasant resort. Of late this has been very frequently demonstrated by some of the leading societies, and in fact, to go back into history, it was proved by the A.S.M.E. as long ago as 1910 when a very successful meeting was held at Atlantic City.

A.S.M.E. history is going to repeat itself in 1927 in that another combination "business and pleasure meeting" is to be held. This time the location will be delightful, White Sulphur Springs in the West Virginia mountains, and the occasion will be the Spring Meeting, May 23–26. A meeting there is by no means an experiment, for some of the sister societies have tried it with unusual success, as their members amply testify.

It can well be stressed that the 1927 Spring Meeting of the A.S.M.E. offers a most unusual opportunity to the membership and their friends for a spring vacation in exhilarating surroundings with congenial companions and at a very low cost. And to the engineer it will at the same time be a profitable vacation, because nothing of the technical program has been sacrificed to the accompanying program of sports and recreation.

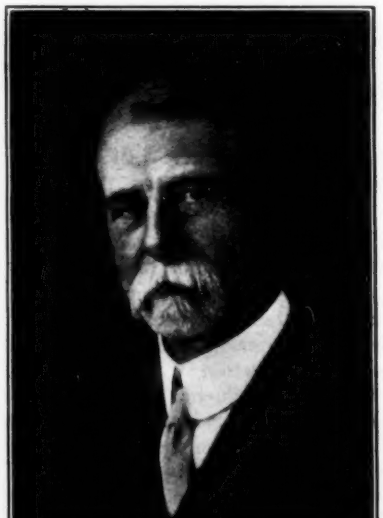
It is not difficult to explain why this is true. The reason is that being in a mountain resort, industrial inspection trips are naturally not on the list of possibilities, and their usual place on the program is occupied by the sport and recreation events. If anything, the technical sessions will be more full and more worth while than they ordinarily are, and it is certain that the invigorating nature of the surroundings will insure keen appreciation.

When it comes to the question of cost of attending the White Sulphur Springs Meeting, a little thought will bring out the fact that it will be comparatively low as Spring Meetings go. In fact, it will be remarkably low when all the advantages are considered. Headquarters will be at The Greenbrier, which with its cottages will furnish the best of accommodations and all sorts of other advantages seldom if ever found elsewhere.

Rates on the American plan as low as $9.00 per day per person are offered. When one considers that the rates include the cost of the banquet and many of the recreation facilities, and that there will be no expenses for shows, etc., which are certain to accumulate into a heavy financial load at a metropolitan center, it will be easily understood why A.S.M.E. "vacation money" will go a long way at White Sulphur Springs.

Henry B. Sargent Dies

HENRY B. SARGENT, of New Haven, Conn., well-known manufacturer and a past vice-president of The American Society of Mechanical Engineers, passed away at the New Haven General Hospital early in the morning of Thursday, February 3. While Mr. Sargent had been in failing health since last May, he continued to be active in his business up to within a week of his death, the immediate cause of which was septicemia.



HENRY BRADFORD SARGENT

Henry Bradford Sargent was born in New York City on March 4, 1851, being the eldest son of Joseph Bradford Sargent and Elizabeth Collier (Lewis) Sargent. His father was a New Englander and his mother a native of Macon, Georgia.

The Sargent family removed to New Britain, Conn., in 1857 and located in New Haven in 1864, so Henry received his early schooling in both of these cities. He prepared for Yale at the New Haven High School.

Mr. Sargent was graduated from the Sheffield Scientific School of Yale University in 1871 with the degree of Ph.B. He was a very active man in college. In the summer and fall of 1870, while an undergraduate, he was a member of the paleontological expedition which under the direction of Prof. O. C. Marsh spent six months west of the Mississippi. One of his outstanding undergraduate achievements was to design and build the six-oared "Sheff" shell which created a sensation when it was rowed to victory by a "Sheff" crew of which Mr. Sargent was a member, in the Yale University Championship boat race on Saltonstall Lake on July 11, 1871.

After his graduation Mr. Sargent immediately entered the hardware-manufacturing concern of Sargent & Company of New Haven, in which his father was the moving spirit.

This industry had grown out of one founded by Elnathan Peck at New Britain in about 1833. The elder Sargent became interested in the business in 1855, and in July, 1864, he reorganized it in New Haven as a stock company composed of himself, his two brothers, and eight employees.

Mr. Sargent, from the time he was thirteen years of age, had worked in the factory during vacations, for it was his father's ambition to "get hardware into the blood" of his six sons. Beginning at the bottom, he proved his worth in various shop departments and in the drafting room. It was not long before he had worked his way to the important position of general inspector of product. At that point he began to have a constantly increasing responsibility in the executive end of the business.

The growth of Sargent & Company during Henry Sargent's fifty-five years' connection with it was such as to make it one of the largest industries in New Haven and one of the largest hardware-manufacturing companies in the world. As long ago as 1887 it

employed 1700 persons, and today the number is around 3000. The number of separate items of hardware catalogued by the concern is approximately 20,000. Mr. Sargent was elected president of Sargent & Company in 1917, and held this position at the time of his death.

Mr. Sargent was a man of wide influence, not only as a successful manufacturer, but also as a very able and active figure in educational, civic, and society affairs. He maintained a deep interest in the affairs of Yale University, both athletic and academic. He served from 1878 to 1912 as a member of the Yale University Athletic Committee and for 19 years was treasurer of the Yale Field Corporation. He was elected a Fellow of the University by the alumni for three terms of six years each following 1902, and declined to run a fourth term.

Unlike his father, who served as mayor of New Haven from 1891 to 1895, Mr. Sargent did not seek political honors. He was, however, a member of the New Haven Common Council in 1883, 1884, and 1885. He was long a director of the Organized Charities and of the New Haven Dispensary, was a trustee of the New Haven Savings Bank and a director of the old City Bank, retaining his directorship when it became the New Haven Bank, until his death.

Mr. Sargent was a member of the Connecticut Academy of Arts and Sciences, of the Graduate, Lawn, and Country Clubs of New Haven, and of the Yale Club and Century Association of New York. In 1923 he was named a national councilor to represent the American Hardware Association in the U. S. Chamber of Commerce.

Mr. Sargent joined The American Society of Mechanical Engineers on June 1, 1898, and was a very active and useful member of the Society. He served on many committees, took an active part in the founding and operation of the New Haven Section, and was deeply interested in the New Haven Machine Tool Exhibition. He was a Vice-President of the Society from 1918 to 1920.

Mr. Sargent is survived by four of his five brothers, all of them graduates of the Sheffield Scientific School, by two sisters, by his wife, Harriet (Oaks) Sargent, by his two daughters, and by two of his three sons.

President James R. Angell of Yale paid the following tribute to Mr. Sargent: "In the death of Henry B. Sargent, New Haven loses one of her finest and most public-spirited citizens, and Yale University loses a distinguished graduate who as a member for 18 years of the corporation rendered her devoted services of the highest value. His name will always be held in grateful memory."

S. W. Dudley.[1]

New Electrical and Mechanical Engineering Hall for Lehigh

Through the generosity of James Ward Packard, M.E. 1884, Lehigh University is soon to have a splendid new Electrical and Mechanical Engineering Hall. Dr. Charles Russ Richards, president of the University has just made public announcement of a gift of $1,000,000 from the well-known electrical and automotive inventor and manufacturer for the purpose of erecting such a building. Architects' plans are ready and construction will begin without delay. This Packard gift is the largest single donation to Lehigh since that from the estate of Asa Packer, the founder of the university.

Preliminary announcement of the plans for the new building have been made by Dr. Richards, and they indicate that it will be a distinguished addition to the great laboratories of the world. It will be 225 ft. wide and 184 ft. deep, making it one of the University's largest buildings. As such it will occupy a prominent position on the campus, and to harmonize with the other buildings it will be in the Gothic style.

The preliminary plans call for laboratories occupying the whole of the rear portion of the building, the 60 ft. by 225 ft. of area to be divided equally between the electrical and mechanical departments.

With a live-load capacity of 400 lb. per sq. ft. it will be possible to mount the heaviest generators, engines, etc., directly upon the floor. The second floor will be a gallery of heavy concrete construction with a 10-ton traveling crane running close under the monitor roof. The basement floor will be level with the street, allowing for the convenient delivery of heavy apparatus, which will be hoisted through a large hatchway to the main floor by means of the crane.

The basement will be a full story in height and will contain an electrical substation, a high-voltage and traction laboratory, a storage-battery room, and a small research laboratory. There will also be concrete flumes and sumps capable of storing and measuring large volumes of water, and various pumps and condensers will be located here. In a court adjoining, covered by a monitor roof, will be the internal-combustion-engine laboratory.

Each laboratory floor will contain ample offices, computation rooms, etc. Special attention will be paid to electric wiring and steam, water, and air piping. There will be well-equipped machine shops, instrument rooms, and storage rooms adjoining the main laboratories.

The engineering drafting rooms will be on the second and third floors of the building, and will be provided with shadowless indirect lighting. Those on the third floor will be adjoined by a museum for the storage and display of models and other material related to machine design. On the second floor also will be located a 40 by 64-ft. electrical and mechanical engineering library and reading room. Immediately below this there will be an auditorium with a seating capacity of 500.

James Ward Packard, who is making this outstanding contribution to the cause of engineering education, is internationally known as the inventor and original manufacturer of the Packard automobile. He has been equally successful, though possibly not so widely known, as a manufacturer of electrical apparatus, being one of the pioneer makers of incandescent lamps on a large scale.

Mr. Packard was born in Warren, Ohio, November 5, 1863, and was graduated from Lehigh University with an M.E. degree at the age of twenty-one. After spending six years in New York, he returned to his old home town, and in 1890 established there the Packard Electric Company which is a thriving industry in Warren, Ohio, today. At this shop in 1899 he designed and built the original Packard automobile, a single-cylinder runabout with light wire wheels, selling for $1200. It was one of the first commercially successful motor cars in America.

The automotive branch of the business was removed to Detroit in 1903 and organized on a large scale as the Packard Motor Company, in the successful career of which Mr. Packard continued to play an active part for twelve years.

[1] Professor of Mechanical Engineering, Yale University. Mem. A.S.M.E.

Second Midwest Power Conference and Engineering and Power Exposition

FRIDAY, February 18, 1927, marked the close of the Second Annual Midwest Power Conference, held in the Coliseum, Chicago, Ill., and which again brought up to date the ever-changing picture of power in industry. Paralleling the Second Annual Midwestern Engineering and Power Exposition, with its 270 well-arranged exhibits covering approximately 80,000 sq. ft. of floor space and representing the foremost manufacturers in the field, this four-day meeting offered a most excellent opportunity for the engineer to learn by both hearing of the progress in engineering and then actually observing the results of putting into practice the principles laid down in the papers.

The widespread interest in the Conference was indicated by the number of engineering societies represented either through their local sections or their professional divisions. Among those participating were the American Institute of Electrical Engineers, The American Society of Mechanical Engineers, the American Institute of Mining and Metallurgical Engineers, the National Electric Light Association, the Western Society of Engineers, and the National Safety Council.

Starting with Tuesday afternoon, February 15, five technical sessions were held, all in the Conference Room of the Coliseum Annex Building. Excursions were arranged for two afternoons, Thursday and Friday, the visitors having choice of two trips on each day. Thursday evening was devoted to a banquet and dance at the Palmer House. An interesting feature of this affair was an address by Samuel Insull.

Technical Sessions

The opening session was called to order with W. S. Monroe[1] in the chair at 2:30 p.m., Tuesday the 15th. Following an address of welcome by Hon. Wm. E. Dever, Mayor of Chicago, Chairman Monroe presented a paper under the title The Middle West and the Power Conference, in which he referred to the engineering problems in connection with the the great railway terminals of Chicago, the problem of controlling the level of the Great Lakes, sewage purification before disposal through the Chicago River, engineering coöperation in the street-improvement program of the city, etc. Other points touched upon were the increasing use of power in industry, smoke abatement, and the great chain of stations being linked in the superpower system.

The Increasing Value of Power to Home and Industry, the second paper in the session, was presented by W. W. Freeman.[2] Some of the principal points emphasized in this contribution were the increase in output per worker through the use of power in industry, and the lightening of housework for the housewife and increased output of farms through rural electrification. He also mentioned the importance of better lighting in industrial plants, and the resulting increase in production and decrease in accidents.

The second session convened at 10:00 o'clock on the morning of February 16, with J. L. Hecht[3] presiding. Three papers were presented at this session: namely, The Use of Power in Steel Mills, by W. Sykes;[4] Improvements in Heat Balance and Costs in Factories of the Corn Products Refining Co., by Joseph J. Merrill;[5] and The Use of Power in the Paper Industry, by V. D. Simons.[6] Mr. Sykes gave a general review of the magnitude of the steel industry and its power requirements, together with the influence that the development of methods of generating and utilizing power have had on the steel industry. Mr. Merrill gave figures taken from the records of the Corn Products Refining Company for the years 1907 to 1926, showing costs of operation during that period, and described some of the improvements made in the coal consumption of the company and the effects of these improvements on the cost figures. The general requirements of heat and power in the pulp and paper industry were presented by Mr. Simons, who also explained the methods of obtaining an economical balance between the two.

C. F. Hirshfeld[7] presided at the Wednesday afternoon session. This session, which convened at 2:00 p.m., was devoted to three papers dealing with power problems in cement mills, industrial plants, and the meat-packing industry. The first, A Cement Mill as a Load and Power Producer, by J. H. Lendi,[8] considered the general nature of a cement plant as a load and the reasons therefor, and involved a general description of a dry-process cement mill. The cement kiln as a producer of clinker with hot gas as a power source also was considered. In a paper by Samuel G. Neiler[9] on Industrial Power-Plant Development, attention was given to the subject of the utilization of waste fuels. The author presented an outline of the study required to be given each individual plant, bringing out the necessity of proper correlation of the many items to be considered in this particular field of engineering. C. H. Kane,[10] presented a paper on The Production and Use of Power in the Meat-Packing Industry, contrasted the early with the present-day methods of producing power, the possibilities for economical production of power, and the economics of central-station service as applied to special processing and heating in the meat-packing industry.

But one session was held on Thursday, February 17, this convening at 10:00 o'clock, with Wm. L. Abbott[11] in the chair. The afternoon was devoted to inspection trips. The papers presented were Economics of Coördinating Gas and Electric Power Supply, by Samuel Insull, Jr.,[12] and Recent Electrical Developments, by Paul Clapp.[13] Among the topics covered by Mr. Insull were separate gas and electric systems for a typical community; savings in combined operation of systems; advantages of joint commercial development; and an estimate of savings in combining the two generating plants.

Friday also had but one session, the afternoon being devoted to excursions. The presiding officer at this session was H. V. Coes,[14] who called the meeting to order at 10:00 o'clock. The first paper on the program, by Samuel A. Taylor,[15] dealt with the Location of and Cost for Central Power Plants. Mr. Taylor emphasized the importance of carefully considering the location of a proposed plant, with particular attention to the necessary fuel and water for the operation of such a plant. A paper by F. S. Collings[16] on Recent Developments in Coal Burning, reviewed late developments in stokers. The burning of coal in pulverized form and the development of the unit pulverizer also formed an interesting part of this paper, as did the information presented on the effect of high- and low-grade coals on plant performance and the influence of air preheating on the plant as a whole. The Fuel Oil Situation in the Central States, a paper by Campbell Osborn,[17] proved very interesting, in that it discussed the present and probable future fuel-oil supply in the Central States, also the use of fuel oil in this area.

Inspection Tours

Two trips were scheduled for Thursday afternoon, one party inspecting the Calumet Station of the Commonwealth Edison Company, while another visited Crane Company's plant. On Friday afternoon two very interesting and instructive tours included the new plant of the Chicago By-Products Coke Company and the South Works of the Illinois Steel Company.

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1 President, Sargent & Lundy, Chicago, Ill. Mem. A.S.M.E.

2 President, Union Gas & Electric Co., Cincinnati, Ohio.

3 Vice-President, Public Service Co., Chicago, Ill. Mem. A.S.M.E.

4 Consulting Engineer, Inland Steel Co., Chicago, Ill. Mem. A.S.M.E.

5 Chief Engineer, Corn Products Refining Co., Chicago, Ill. Mem. A.S.M.E.

6 Consulting Engineer, Chicago, Ill.

7 Research Engineer, Detroit Edison Co., Detroit, Mich. Mem. A.S.M.E.

8 Chief Electrical Engineer, Universal Portland Cement Co.

9 Consulting Engineer, Neiler Rich & Co., Chicago, Ill. Mem. A.S.M.E.

10 Mgr., Construction Dept., Swift & Co., Chicago, Ill.

11 Chief Operating Engineer, Commonwealth Edison Co., Chicago, Ill. Past-President, A.S.M.E.

12 President, Midland Utilities Co., Chicago, Ill.

13 Mgr., Dir. N.E.L.A., New York, N. Y.

14 Vice-Pres., Belden Mfg. Co., Chicago, Ill. Mem. A.S.M.E.

15 Consulting Engineer, Pittsburgh, Pa.

16 Mechanical Engineer, Sargent & Lundy, Chicago, Ill. Mem. A.S.M.E.

17 Economist, Marland Oil Co.

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Theory of Water Hammer

THEORY OF WATER HAMMER. By Lorenzo Allievi, C.E. Translated from the Italian by Eugene E. Halmos, Mem. Am.Soc.C.E. Rome, Italy, Typography Riccardo Garroni. Paper, $7^1/_2 \times 10^3/_4$ in., Part I (text), 122 pp.; Part II (diagrams), 90 pp. Obtainable through the Secretary of the A.S.M.E., 29 W. 39th St., New York.

THE publication of this English translation of Allievi's justly celebrated work will be welcomed by all hydraulic engineers, and especially by those who are interested in the physical and mathematical theory of the propagation and interference of acoustic or pressure waves in long tubular conduits.

Perhaps the first in point of time, Joukovsky laid the foundation for the present commonly accepted acoustic or pressure-wave theory of the formation, propagation, and combination of pressure waves in pipes. Joukovsky presented a clear physical picture and laid the foundation for future work, but did not, except for a special case, carry his investigation to a point furnishing formulas and methods useful for engineers. This Allievi undertook to do.

With entire originality, however, he does not present the physical picture as does Joukovsky, but develops his basic equations rather from the mathematical viewpoint. While this strategy leads more directly to the development of formulas, the absence of the physical picture is to be regretted, and Allievi's treatment would gain in interest and utility with somewhat greater attention to the physical phenomena involved.

The work is presented in two parts, Notes I to V in number, and Plates or Diagrams. The notes are further introduced by an abstract of Allievi's original paper of 1902 by Professor Neeser of the University of Lausanne.

The five notes are entitled respectively: General discussion of method; water hammer in closure; water hammer of opening; counter blow during return to regimen; and phenomena of resonance. These headings give a general idea of the scope of the work.

The treatment, as is common with such problems, is based on certain ideal conditions which are not realized in practice. Most important among these is the omission of all influence or effect due to pipe-line friction. Other assumptions are a line of uniform section, perfect reflection of the pressure waves at the two ends of the line, and, in several special problems, a linear law of gate closure or opening. These limitations and specially assumed conditions must not be overlooked in applying the formulas, which are built up on such a foundation.

With the case simplified as it is by these special assumptions, it becomes possible to express the variables of the line in terms of two simple line characteristics, and in terms of which the solutions assume peculiarly simple and elegant forms. In particular the solution of an interlocked series of values, such as these problems present, becomes possible through relatively simple and elegant geometrical constructions, all of which is fully set forth in Allievi's treatment.

Unfortunately for Allievi in English-speaking countries, his name has long been associated with a particular formula deduced by him through a special procedure involving a series of particular assumptions and in no wise representing the generality of treatment which his method as a whole presents. This formula, used in cases to which it did not and could not apply, has called in question the validity of his work and has thrown unmerited doubt on his treatment. The particular physical assumption on which this restricted Allievi formula is based was that, in closure, for instance, at a linear rate of area reduction, the excess pressure rising rapidly to a certain value would thereafter remain substantially constant at such value. This assumption, together with certain other special steps in treatment, gives the particular formula which has so long been connected with Allievi's name. The publication of this more complete treatment should serve to place this particular formula where it belongs, as relating purely to a special set of conditions and which may only accidentally be fulfilled.

Perhaps the most interesting feature in connection with this particular formula is the fact (which possibly had escaped Allievi's notice) that, due to the special assumption made, and to the particular steps in the process of reduction employed, the acoustic or pressure-wave feature is entirely eliminated from the physical picture and a result is reached which is identical with that given by a direct application of Newton's laws to the mass of water in the pipe as a whole, and with no reference whatever to pressure or acoustic waves.

The chief caution which should be exercised in using Allievi's elegant and relatively simple methods, both analytical and geometrical, bears upon the fact that this simplicity has been obtained at the expense of some loss in generality of treatment.

The entire omission of all influence due to friction and the assumption of complete physical reflection of the pressure wave from a partially open valve with water issuing, are the most serious departures from actual conditions.

The importance of pipe-line friction will depend on the characteristics of the case. It may be unimportant or it may assume a value of definite significance. For closure the influence of friction is relatively large at the start, diminishing rapidly with the decrease in velocity. In the case of openings, the influence of friction is minimum at the start, when as a rule the greatest pressure drop occurs, and increases with the increase in velocity. Generally speaking, the influence of friction is less important where the maximum pressure change occurs at the beginning of the movement, and is more important when it occurs near or at the end of the movement.

Likewise in partial valve movement, opening or closure, the influence of friction may not infrequently assume definite importance.

The same physical picture as developed by Joukovsky and as implied in Allievi's equation, may, with no analytical difficulty, be extended to include friction, such equations reducing identically to Allievi's forms when expressed in terms of the same variables and with the assumption of zero friction. Such extension, however, removes the equations from the possibility of treatment in the simplified forms and with the geometrical constructions given by Allievi. This is only the natural price which must be paid for greater generality of treatment.

The influence of imperfect reflection at a partially open valve may also be included in the same general equations, once we are able to assume a particular percentage of reflection as realized. Such extension adds in no significant degree to the solution of the equations and the only practical difficulty lies in knowing what coefficient or percentage to assume in any particular case.

The purpose in calling attention to these points is only by way of a caution that in using the relatively simple and direct methods furnished by Allievi's treatment, the fact must not be overlooked that they apply strictly to an ideal case only, and one from which the actual case may depart in considerable and perhaps significant degree.

The second part of the work as published consists of figures and diagrams, 64 in number. These include a number of simple and elegant geometrical constructions and methods of treatment, and add in very pronouced degree to the value of the text. It is unfortunate that the economic limitations of the publication necessitated the printing of these from the original Italian plates. It results that the legends are all in Italian, and this fact may narrow somewhat, for most engineers, the readiness of use of such diagrams and geometrical material. In many cases, however, the diagrams are sufficiently self-explanatory to present no difficulty in use, especially with suitable reference to the text.

The placing of this work of Allievi's within the ready reach of the English-reading world furnishes a most welcome addition to the scanty literature of the subject, and the translator and those who have made possible the publication are to be congratulated on having rendered this important service to the engineering profession.

W. F. Durand.[1]

Power-Plant Testing

Power Plant Testing. By James A. Moyer. McGraw-Hill Book Co. Inc., New York, 1926. Cloth, 6 × 9 in., 609 pp., illus., $5.

THIS is the third edition of a well-known text on the testing of power-plant equipment, and the work has been considerably enlarged and rewritten.

The first nine chapters discuss the measurement of basic quantities, such as pressure, temperature, moisture in steam, fluid flow, power, gas analysis, and calorimetry. One chapter is devoted to the planimeter, and another to the steam-engine indicator and reducing motions.

Some of the material in these chapters is drawn from preliminary drafts in course of preparation for the A.S.M.E. Code on Instruments and Apparatus. In order that widespread comment may be stimulated, portions of this material have occasionally been published in Mechanical Engineering and the author has quoted these extensively. In view of the preliminary nature of this material, this is unfortunate. Not only has the Society's main committee not approved these sections for submission to Council, but the individual sub-committee has not even completed its labors. Much of this material will doubtless be changed radically before final adoption by the Society.

In addition to ill-chosen quotations, there are several descriptions of instruments that have been off the market for some years, and methods of correction and calculation are recommended that have ceased to be regarded as representative of good practice.

Later chapters of the book cover the testing of specific types of apparatus—engines, turbines, boilers, etc. Here again there is extended quotation from the A.S.M.E. Test Codes, but the author fails to make it clear just where his quotations give place to his own additions. Moreover, in some instances, as before, some of the material quoted is merely preliminary, and some of the quotations are incomplete or interspersed with the author's comments. In no case are these facts clearly indicated. Unapproved material should be clearly indicated, and the incomplete or annotated quotation of approved material should likewise be made very clear.

The volume, however, will be of value as a textbook in engineering colleges, where it should be useful in bringing before students information on methods, and a first-hand acquaintance, with the A.S.M.E. Test Codes, in their general form. Of course teachers should take pains to recommend to their students that when the need to use such documents commercially, they seek the latest revision approved by the Society.

C. H. Berry.[2]

[1] Professor of Mechanical Engineering, Leland Stanford University, Stanford University, Cal. Past-President, A.S.M.E.

[2] Associate Editor, *Power*, New York, N. Y. Mem. A.S.M.E.

Books Received in the Library

Administration of Vocational Education of Less than College Grade. By J. G. Wright and Charles R. Allen. John Wiley & Sons, New York, 1926. Cloth, 5 × 8 in., 436 pp., graphs, forms, tables, $3.

The work of two men with unusual experience in the administration and analysis of vocational education, this book is a careful, detailed discussion of the responsibilities of the administrator of vocational education and of the ways in which school and work may be combined to supplement each other.

Anleitung zu Genauen Technischen Temperaturmessungen. By Oscar Knoblauch and K. Hencky. Second edition. R. Oldenbourg, München and Berlin, 1926. Paper, 6 × 9 in., 174 pp., illus., diagrams, 9 mk.

While physicists and engineers can obtain a knowledge of the laws underlying the various ways of measuring temperatures and of the methods used from textbooks of physics and practical handbooks, they do not find in these, however, advice on certain topics of great practical importance, such as the proper installation of measuring instruments in machines and furnaces so that sources of error will be minimized. It is with this question that the present book deals. It discusses the possible sources of error in the various industrial applications of thermometers and pyrometers, their probable effect on the readings, and the ways in which they can be eliminated.

Art de L'Ingénieur et Métallurgie. Compiled by L. Descroix. (Extrait du vol. 5, Tables Annuelles de Constantes et Données Numériques.) Gauthier-Villars & Co., Paris; University of Chicago Press, Chicago, 1926. Paper, 9 × 11 in., 251 pp., tables, 11 × 9 in. With 25 per cent discount allowed to Society members, price is 78.75 francs, unbound, or 94.50 francs, bound. Apply to M. Charles Marie, General Secy., 9 Rue de Bagneux, Paris, VI^e^.

The annual tables of numerical data and constants summarize those that have appeared in scientific and technical publications throughout the world and present them in convenient form for reference, with citations of the sources from which they are taken. The volume at hand, extracted from volume 5 of the tables, contains the data of importance to engineers and metallurgists which were published in the years 1917–1922, inclusive. It makes available much recent information on the physical and chemical properties of structural materials, on fuels and metals, and on electrical and magnetic constants. Similar volumes are available for the years from 1912 to 1916. The series is a complement to the recently published "International Critical Tables." It is published under the patronage of the International Research Council.

Automobile. By Reinhold Thebis. Walter de Gruyter & Co., Berlin and Leipzig, 1926. Cloth, 4 × 6 in., 107 pp., illus., 1.50 r.m.

This little work describes with great conciseness the general construction of the gasoline automobile, the motor truck, and the electric truck.

Beiträge zur Geschichte der Technik und Industrie; V. D. I. Yearbook, 1926. By Conrad Matschoss, editor. Cloth, 8 × 11 in., 354 pp., illus., portraits, 16 r.m.

The latest of the valuable yearbooks issued by the Society of German Engineers and devoted to the history of engineering, covers an unusually wide range. Distilling, oil firing, the chemical utilization of wood, lightning rods, coining, calculating machines, and electric hoisting machinery are the subject of historical papers. Biographies of Felix Grashof and Hermann Gruson are included, and there are papers upon two fifteenth-century engineers, Biringuccio and Guiliano da San Gallo. Twelfth-century engineering is treated in a review of the Schedula Diversarum Artium of Theophilus Presbyter. New features included this year are abstracts of important articles published elsewhere and an index to the literature of the year.

Chemical Engineering Economics. By Chaplin Tyler. McGraw-Hill Book Co., New York, 1926. (Chemical Engineering series.) Cloth, 6 × 9 in., 271 pp., charts, tables, $3.50.

"Virtually all of our attention in the colleges," says Mr. Tyler, "is turned toward the technical side of industrial enterprises,

whereas in the actual practice of chemical engineering as a profession, the economic and business considerations usually are controlling." His book is intended to help bridge the gap that separates classroom instruction from industrial practice, by discussing such topics as plant location, layout, and design; cost accounting, operating costs, management, fuels, operation, and control. The general characteristics and magnitude of the chemical industries are also considered.

ELECTRIC POWER STATIONS. By L. W. W. Morrow. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 326 pp., illus., diagrams, tables, $4.

Mr. Morrow's book treats the question of the production, transmission, and distribution of electrical energy on a large scale from a broad viewpoint. Leaving to the specialist the separate details of the elements of the problem, he discusses the principles, as exemplified by present practice and opinion, which guide the engineer and the executive in the selection of equipment and its assemblage at different locations along the stream of electrical energy, so that this energy may be produced and carried to the consumer efficiently and economically. He tries to coördinate the different engineering principles and the variety of equipment, and to weigh the respective elements in relation to the whole system.

ELECTRIC TRAINS. By R. E. Dickinson. Longmans, Green & Co., New York, Edward Arnold & Co., London, 1927. Cloth, 6 × 9 in., 292 pp., illus., diagrams, tables, $6.

The aim of this book is to present those matters of primary interest to the railroad engineer without the use of advanced mathematics. Emphasis is therefore placed on the fundamental principles of electric traction, the apparatus in use, and similar matters related to the running and maintenance of trains, while matters relating to the generation, transmission, and transformation of electric power have been omitted.

ELEMENTARY MECHANISM. By A. T. Woods and A. W. Stahl; revised and rewritten by Philip K. Slaymaker. D. Van Nostrand & Co., New York, 1926. Cloth, 6 × 9 in., 250 pp. illus., diagrams, tables, $3.

The purpose of the original authors of this work was to prepare a textbook on kinematics, suitable in size to the requirements of students of engineering. This was accomplished by avoiding purely theoretical discussions and confining the text to a clear description of those mechanical movements that might be of practical use and the discussion of the principles that underlay them. After many years of popularity, this new edition has been prepared. In it much of the original text has been rewritten by Professor Slaymaker, new matter has been added, modern applications have been introduced, and the book brought up to date generally.

ELEMENTS OF ASTRONOMY. By Edward Arthur Fath. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 9 in., 307 pp., illus., tables, $3.

Intended primarily for use by college freshmen with no mathematical training except in elementary algebra and plane geometry, this book aims to present the necessary physical concepts so that they will obtain the main facts of the subject and have also an elementary understanding of the principles and methods involved in modern astronomical investigation.

EMPLOYMENT STATISTICS FOR THE UNITED STATES. Edited by Ralph G. Hurlin and William A. Berridge. Russell Sage Foundation, New York, 1926. Cloth, 6 × 9 in., 215 pp., forms, $2.50.

In 1922 the American Statistical Association undertook a study of methods for collecting and presenting statistics on employment, with the object of removing the unsatisfactory character of the statistics available hitherto. The committee, consisting of a representative body of experts, has studied the various uses for employment statistics, the methods of procedure in gathering and checking them, the forms of records, and the methods of analysis and presentation in current use; and presents its conclusions in this report.

EVOLUTION AND DEVELOPMENT OF THE QUANTUM THEORY. By N. M. Bligh. Longmans, Green & Co., New York; Edward Arnold & Co., London, 1926. Cloth, 6 × 9 in., 112 pp., portrait, $3.

This small volume attempts to supply something intermediate between the isolated references to the quantum theory which are found in treatises on physics and the detailed textbooks on the subject. It traces the rise of the theory, gives a mathematical deduction of each important law, as it arises; and indicates the difficulties encountered and the means by which they are overcome. In a second section the more important applications of quantum principles to general problems of physics are discussed. The book is a concise handbook which will meet the needs of the general scientific reader, as far as the nature of the subject will permit.

FLUGLEHRE. By Richard Von Mises. Third edition. Julius Springer, Berlin, 1926. Paper, 5 × 8 in., 321 pp., diagrams, tables, 12.60 r.m.

An elementary text dealing with the mechanical principles underlying present methods of flight. The book discusses the resistance of the air, supporting surfaces, gliding, aerofoils, motors, steering, stability, flying, landing, etc. Higher mathematics is avoided and the book may be understood by those without college training. The work is based on courses of instruction given to student officers in the flying corps of the German army in 1913 and 1916.

FUNDAMENTALS OF THE LOCOMOTIVE MACHINE SHOP. By Frank M. A'Hearn. Simmons-Boardman Publishing Co., New York, 1926. (Railwaymen's handbook series.) Fabrikoid, 5 × 8 in., 242 pp., illus., diagrams, $2.50.

Intended for foremen, machinists, and others concerned with these shops. The author describes many of the simple operations in machining locomotive parts, explains the methods and tools commonly used, and gives suggestions on the proper installation and operation of machine tools. The book is based upon the methods used in various American shops.

GEORG AGRICOLA, 1494–1555. By Ernst Darmstaedter. 96 pp., illus.
BERG-, PROBIR- UND KUNSTBÜCHLEIN. By Ernst Darmstaedter. 206 pp., illus. Verlag der Münchner Drucke, Munich, 1926. 2 vols. (Münchener Beiträge zur Geschichte und Literatur der Naturwissenschaften und Medizin; heft 1 & heft 2/3.) 6 × 9 in., paper, respectively, 6 mk. and 7 mk.

These attractively printed monographs are the first of a series upon the history and literature of the natural sciences and medicine, to be published at irregular intervals. Each of the series is to be devoted to a particular period or an important individual. A historical sketch of the period or an estimate of the individual will be given, together with an accurate bibliography of first editions and principal writings.

The monograph on Agricola contains a brief outline of his life, a detailed summary of the contents of his principal works, a bibliography, and a list of references to literature about him. It is illustrated by reproductions of title pages and of illustrations from De Re Metallica.

The second pamphlet deals with the small handbooks on mining, assaying, and alchemy. These were chiefly books of recipes, practical hints, etc. They began to appear about 1505, and were published in many editions during the sixteenth to the eighteenth centuries.

The development of mining and assaying, as shown by these books, is here discussed, and an extensive bibliography is given. Both books will interest students of early engineering.

DIE GEWINDE; Erster Nachtrag. By G. Berndt. Julius Springer, Berlin, 1926. Boards, 6 × 9 in., 180 pp., illus., diagrams, tables, 16.75 r.m.

Instead of preparing a new edition of his valuable book, Die Gewinde, Dr. Berndt issues this supplement to it, containing an account of developments since 1925 and also corrections of errors in the original book. The changes are numerous and important enough to make this volume necessary to all users of the work. The book covers developments up to June 30, 1926.

HYDRO-ELECTRIC HANDBOOK. By William P. Creager and Joel D. Justin. John Wiley & Co., New York, 1927. Fabrikoid, 6 × 9 in., 897 pp., illus., diagrams, maps, tables, $8.

In preparing this reference book the contributors have aimed to present, in the usual "handbook" form, a compendium of practice and theory covering all phases of hydroelectric work. The factors which determine the power available in a stream are discussed, the general design of the hydraulic plant and the design of dams, canals, flumes and pipes are treated. Special chapters treat of the sub-

structure and superstructure of the power house and the turbines. The electrical design and equipment, and transmission lines are then taken up. The volume closes with chapters on investigations and reports, on river gaging and on the operation of hydroelectric properties.

JAHRBUCH DER DEUTSCHEN GESELLSCHAFT FÜR BAUINGENIEURWESEN, 1926. V.D.I. Verlag, Berlin, 1926. Paper, 6 × 8 in., 229 pp., illus., portraits, map, tables, 10. r.mk.

The second yearbook of the German Society for Structural Engineering is designed to present the usual information about it and also to supply certain data frequently wanted by engineers. Interesting papers are included on developments during the year in concrete and reinforced concrete, on underground structures in cities, and on flying fields. The most valuable material, however, is in the summaries. These comprise, among others, statistics of the large hydraulic power plants of Germany, a list of the important engineering construction of the year, a catalog of the dissertations presented to German universities during the years 1918–1926 for the degree of Doctor of Engineering, and a bibliography of monographs for structural engineers.

KRITISCHE DREHZAHLEN ALS FOLGE DER NACHGIEBIGKEIT DES SCHMIERMITTELS IM LAGER. By Charles Hummel. V.D.I. Verlag, Berlin, 1926. (Forschungsarbeiten auf dem gebiete des Ingenieurwesens, heft 287.) Paper, 7 × 10 in., 48 pp., illus., diagrams, 3.80 mk.

Professor Stodola has recently called attention to a new critical speed, which differs from that caused by the elastic deformation of a revolving shaft of a machine, and which has its origin in the yielding of the oil layer in the bearing. The author of this pamphlet, at Professor Stodola's suggestion, has undertaken to place the theory of this phenomenon on a broad base and to confirm it by experimental work.

The writer first investigated the problem mathematically and then proceeded to test his conclusions by experiments. The result was a confirmation of the theory. Methods for making these critical speeds innocuous, by proper design of the bearings, are indicated.

MACHINE DESIGN PROBLEMS. By S. J. Berard and E. O. Waters. D. Van Nostrand Co., New York, 1927. Cloth, 6 × 9 in., 118 pp., diagrams, tables, $1.50.

A collection of problems prepared to supplement the Elements of Machine Design issued by the same authors.

NEW METHODS IN EXTERIOR BALLISTICS. By Forest Ray Moulton. University of Chicago Press, Chicago, 1926. Cloth, 6 × 9 in., 259 pp., $4.

Beginning in 1918, Dr. Moulton has been investigating this subject, with the coöperation of the United States Army. The result of this work appears here as a new method for handling ballistic problems, accompanied by the results of a series of proving-ground and wind-tunnel experiments made to test the fundamental theory. The book completes the problem of exterior ballastics from the theoretical point of view, placing it, the author says, on a plane where apparently it will require no essential improvement for a long time to come.

PRACTICE OF LUBRICATION. By T. C. Thomsen. Second edition. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 9 in., 616 pp., illus., diagrams, $6.

The work of an engineer with long experience in the oil trade, this book is a useful work of reference for all who wish information on the theory of lubrication, the properties of the various lubricants, and the selection of proper lubricants for the principal types of machinery. The new edition has been revised and some new topics have been included.

DER ZUGVERSUCH. By G. Sachs and G. Fiek. Akademische Verlagsgesellschaft, Leipzig, 1926. Paper, 6 × 9 in., 252 pp., illus., diagrams, 12 mk.

A discussion of tensile-strength tests by two experienced German engineers, addressed to those who have the task of drawing useful conclusions from tests of materials, especially makers and users of structural materials, and engineers of tests. It contains, in addition to directions for the practical conduct of our most important test of materials, a thorough discussion of all the points of view which are of importance for the process of testing, on the one hand, and for the interpretation of the results, on the other.

In the first part of the book the authors discuss thoroughly the signification of strength, ductility, and other characteristics, the influence of nicks and other flaws, and the relation of tensile tests to other tests. A section is devoted to the influence of combined requirements.

The second part briefly reviews the structure of materials and also those influences on tensile tests, such as temperature, speed, and cold working, which presuppose a knowledge of structure. The third section discusses the choice of equipment for testing for any given purpose.

An appendix, describing the shapes of test pieces used in different countries, and a bibliography are given.

U.E.S. Report for 1926

BELOW is a summary of the report of the treasurer of the United Engineering Society for the calendar year 1926. The officers of the U.E.S. for the coming year are: President, Bancroft Gherardi; First Vice-President, Roy V. Wright; Second Vice-President, Francis Lee Stuart; Secretary, Alfred D. Flinn; Treasurer, Jacob S. Langthorn; Assistant Treasurer, Henry A. Lardner. Finance Committee: Roy V. Wright, Chairman, Lincoln Bush, W. L. Saunders, Arthur S. Dwight, and the President, ex-officio.

The membership of the Board of Trustees for 1927 is as follows:

Representing the Civil Engineers: Francis Lee Stuart; Lincoln Bush; George Gibbs.

Representing the Mechanical Engineers: W. L. Saunders; Walter S. Finlay, Jr.; Roy V. Wright.

Representing the Mining Engineers: J. Vipond Davies; J. V. N. Dorr; Arthur S. Dwight.

Representing the Electrical Engineers: Bancroft Gherardi; George L. Knight; Calvert Townley.

SUMMARY OF REPORT

OPERATION OF BUILDING

Credit balance January 1, 1926		$ 8,641.03
Miscellaneous adjustments		1.50
Building revenue, 1926	$130,211.60	
Building expenditures, 1926	104,787.66	25,423.94
		$ 34,066.47
Annual payment to Dep. & Renewal Fund.	12,000.00	
Additional payment to Dep. & Ren. Fund..	3,531.25	
Added to Real Estate	6,840.98	22,372.23
Credit balance December 31, 1926		$ 11,694.24

OPERATION OF LIBRARY

Maintenance revenue	41,844.39	
Maintenance expenditures	42,404.53	
Deficit December 31, 1926		−560.14
Service Bureau revenue	19,145.95	
Service Bureau expenditures & adjustments	18,068.86	
Operating balance and adjustments	1,077.09	
Credit balance December 31, 1925	856.25	1,933.34
Credit balance December 31, 1926		$ 1,373.20

FUNDS AND PROPERTY

Funds held by U.E.S. Dec. 31, 1926 (book value):	
Depreciation and Renewal	$ 215,887.39
Engineering Foundation	489,843.46
Henry R. Towne Engineering	49,987.58
Library Endowment	102,458.67
Reserve for Depreciation of Capital of Library	4,000.00
General Reserve	10,000.00
John Fritz Medal (U.E.S. custodian)	3,500.00
Total	875,677.10
Real Estate owned by U.E.S., cost to Dec. 31, 1926	1,973,410.42
Operating cash and petty cash	11,044.95
Accounts receivable	2,875.76
Value of Library (as appraised for insurance)	342,456.00
Total property for which U.E.S. is trustee or custodian..	$3,205,464.23